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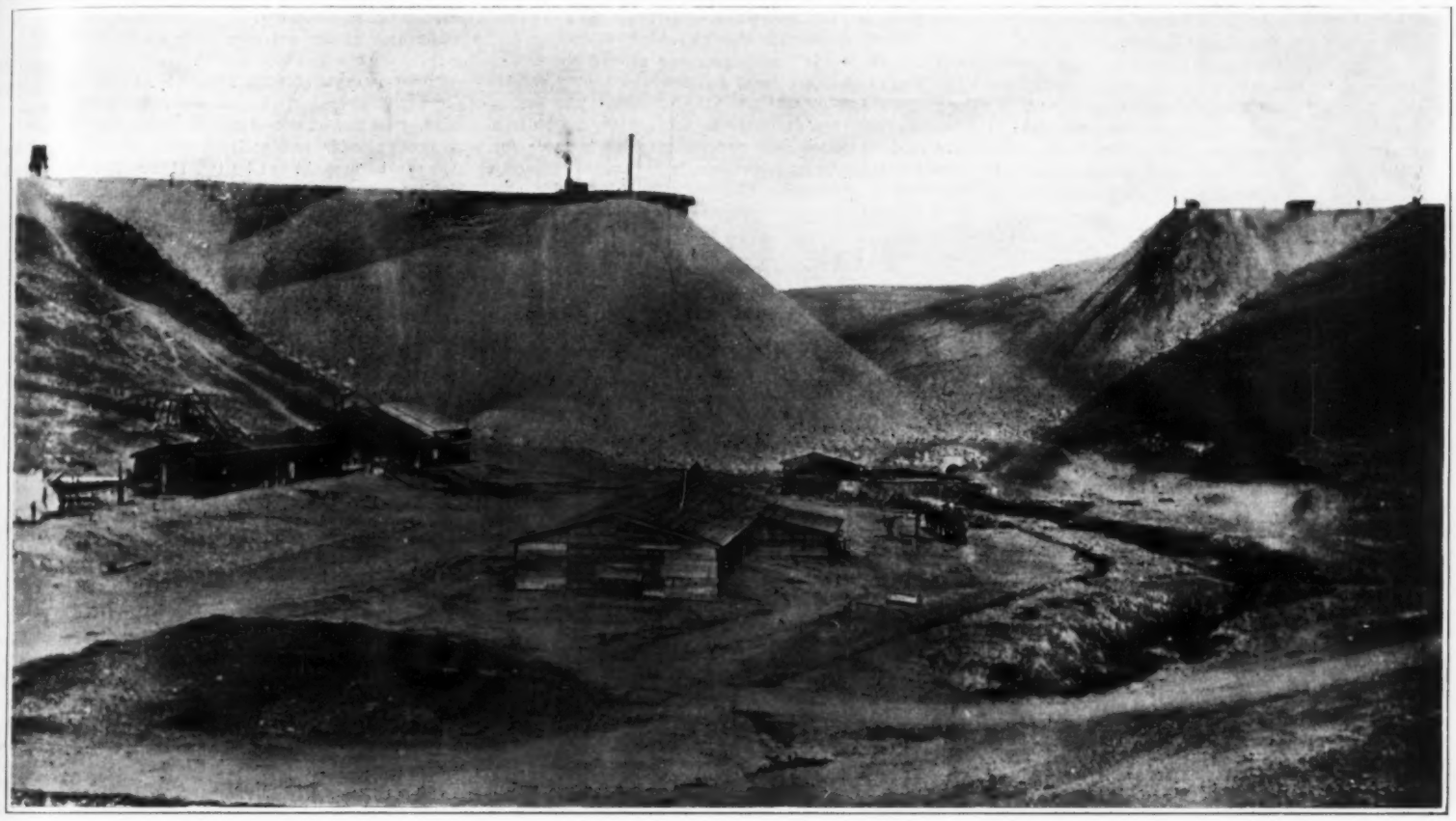


Fig. 1.—A Continuous Unloader Working on a Fill of the Western Pacific Railroad, California. View from the Bottom of a 125-Foot Fill.

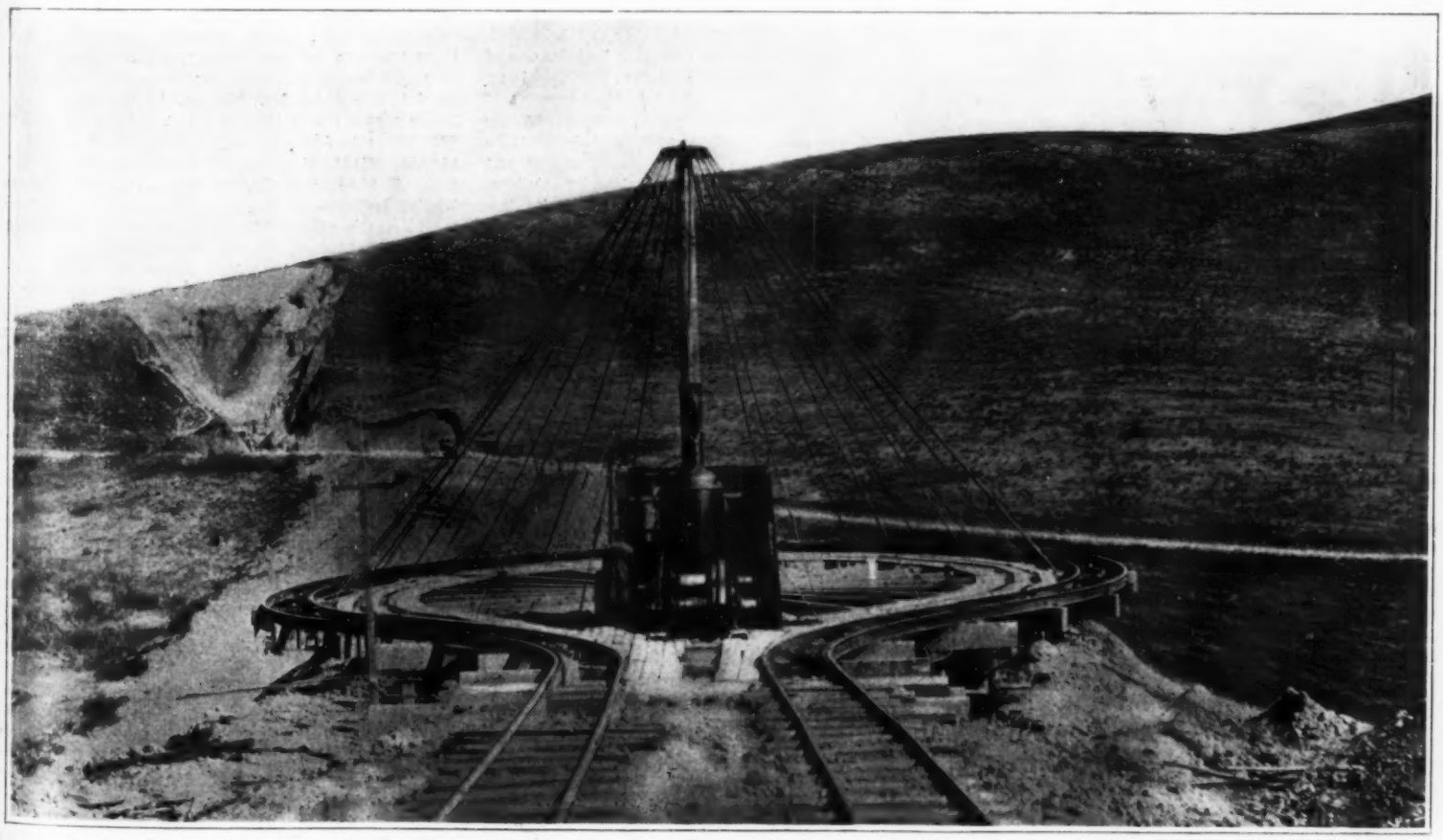


Fig. 2.—Near View of the Continuous Unloader in a 114-Foot Fill.

## MECHANICAL HANDLING OF MATERIALS ON A LARGE SCALE.

# A Continuous Unloader At Work

## On the Western Pacific Railroad, California

A REMARKABLE type of continuous unloader of unique design and construction in use in California is seen at work in the accompanying illustrations, Figs. 1 and 2, on 125 feet and 114 feet fills. This continuous unloader is a thoroughly practical device, by means of which cars may be unloaded continuously and with the least possible delay. It was designed to take the place of trestles in the construction of high embankments. The photographs show its use on two of the largest fills on the Western Pacific Railroad at Altamont, Cal., where it has proved most satisfactory, the work being well done, in less time and for less money than would have been possible by any of the old methods in use for this class of work.

The danger from the use of high temporary trestles is eliminated by this method. The unloader consists of a circular track, resting on radials and partially supported by rods suspended from a mast arranged at the center of the structure. The entire frame rests on rollers, under which are short stringers, and is moved ahead by its own power, ten or fifteen feet at a time as the work progresses. At the center of the unloader is placed a double drum hoisting engine as indicated in the illustration Fig. 2. This hoist operates a cable that leads around the circular track, between the rails and is held in place by rollers. A train of eight, ten or twelve loaded cars is pushed by a locomotive to the unloader, where they are picked up by the cable and hauled around.

The cars are unloaded while in motion, and one man with a dumping stick can dump them as fast as they come to him. Two men knock the chain loose, two others pull them back and chain up. One engineer, one gripman, and two block men complete the force required to operate the unloader.

While the loaded cars are going around the circle, the engine switches from the delivery, to the receiving track and is ready for the empties. The empty cars having been delivered to the engine, the ball on the cable is pulled back and the machine is ready for another train. On this work, the train of cars was handled faster than a 65-ton steam shovel, side cutting in good material, could load them. The unloader can easily take care of all the material loaded by two steam shovels.

The maximum time consumed in moving the machine forward is 90 minutes, and this work is usually done during a meal hour, so as not to delay the steam shovel. Where the material in the fill does not settle very rapidly, the move is made in about 30 minutes. One fill on which this unloader was used, was 125 feet high and 750 feet long. The other was 114 feet high and 1,200 feet long, as shown in the photographs. The unloader is readily taken apart and can be shipped on any flat car.

The cost of the unloader fully equipped, including donkey engine, is about $5,500. For its operation is required a crew of nine men, viz., three mechanics and six laborers. The cost per cubic yard depends entirely on the output of the steam shovel or shovels, as the unloader can easily handle all the material that can be brought out by two steam shovels in good digging.

# The Elements

## Their Inter-relation and Origin

### Sir William Ramsay's British Association Address

SIR WILLIAM RAMSAY, in his recent presidential address before the British Association, dealt principally with some of the fundamental facts regarding the elements, the relations between them, and those remarkable side lights upon their nature and origin which have of late years flashed out from the discoveries of Becquerel, the Curies, and their followers. No small share both in the experimental development of the new field thus opened, and in the theoretical discussions of the bearing of these remarkable discoveries upon the origin of the elements has been taken by Sir William Ramsay himself; this fact lends a special interest to the account of his presidential address, published in *Nature* and reproduced in abridged form below.

After briefly reviewing the ideas of the ancients regarding their so-called elements, the speaker went on to a discussion of the elements in the modern conception of the word. Since Dalton's days the chemist has been in the habit of regarding compounds as consisting of aggregations of atoms of elements, united in definite proportions Yet the more daring spirits, even of Dalton's days, were not without hope that the elements themselves might prove decomposable. Davy, indeed, went so far as to write, in 1811: "It is the duty of the chemist to be bold in pursuit; he must recollect how contrary knowledge is to what appears to be experience. . . . To enquire whether the elements be capable of being composed and decomposed is a grand object of true philosophy." And Faraday, his great pupil and successor, at a later date, 1815, was not behind Davy in his aspirations, when he wrote: "To decompose the metals, to re-form them, and to realize the once absurd notion of transformation—these are the problems now given to the chemist for solution." Indeed, the ancient idea of the unitary nature of matter was in those days held to be highly probable.

It has been customary for several years past to publish annually a table of the atomic weights, revised by a special committee.

In the table for 1911, of eighty-one elements no fewer than forty-three have recorded atomic weights within one-tenth of a unit above or below an integral number. Karl Pearson assures us that the probability against such a condition being fortuitous is 20,000 millions to one.

Such a fact as this almost irresistibly forces us to the conclusion that the elements are in some way related as to their mode of origin. The relation between the elements, has, however, been approached from another point of view. The periodicity in the properties of the elements, as pointed out by Newlands and Mendeléeff, makes it practically impossible for us to conceive of these elements as independent entities. A consideration of Mendeléeff's table naturally suggests the question as to the proper position in that table of the newly discovered radio-active elements and their congeners. Says Sir William Ramsay:

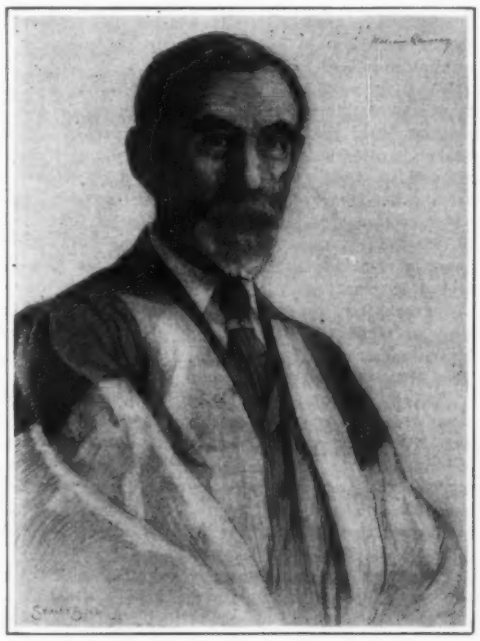
"The discovery of radioactivity by Henri Becquerel, of radium by the Curies, and the theory of the disintegration of the radioactive elements, which we owe to Rutherford and Soddy, have indicated the existence of no fewer than twenty-six elements hitherto unknown. To what places in the periodic table can they be assigned? But what proof have we that these substances are elementary? Let us take them in order.

"Beginning with radium, its salts were first studied by Madame Curie; they closely resemble those of barium—sulphate, carbonate, and chromate insoluble; chloride and bromide similar in crystalline form to chloride and bromide of barium; metal, recently prepared by Madame Curie, white, attacked by water, and evidently of the type of barium. The atomic weight, too, falls into its place; as determined by Madame Curie and by Thorpe, it is 89.5 units higher than that of barium; in short, there can be no doubt that radium fits the periodic table, with an atomic weight of about 226.5. It is an undoubted element. But it is a very curious one. For it is unstable. Now, stability was believed to be the essential characteristic of an element. Radium, however, disintegrates—that is, changes into other bodies, and at a constant rate. If 1 gram of radium is kept for 1,760 years, only half a gram will be left at the end of that time; half of it will have given other products. What are they? We can answer that question. Rutherford and Soddy found that it gives a condensable gas, which they named "radium-emanation;" and Soddy and I, in 1903, discovered that, in addition, it evolves helium, one of the inactive series of gases, like argon. Helium is an undoubted element, with a well-defined spectrum; it belongs to a well-defined series. And radium-emanation, which was shown by Rutherford and Soddy to be incapable of chemical union, has been liquefied and solidified in the laboratory of University College, London; its spectrum has been measured and its density determined. From the density the atomic weight can be calculated, and it corresponds with that of a congener of argon, the whole series being: helium, 4; neon, 20; argon, 40; krypton, 83; xenon, 130; unknown, about 178; and niton (the name proposed for the emanation to recall its connection with its congeners, and its phosphorescent properties), about 222.4. The formation of niton from radium would therefore be represented by the equation: radium (226.4) = helium (4) + niton (222.4). Niton, in its turn, disintegrates, or decomposes, and at a rate much more rapid than the rate of radium; half of it has changed in about four days. Its investigation, therefore, had to be carried out very rapidly, in order that its decomposition might not be appreciable while its properties were being determined. Its product of change was named by Rutherford "radium A," and it is undoubtedly deposited from niton as a metal, with simultaneous evolution of helium; the equation would therefore be: niton (222.4) = helium (4) + radium A (218.4). But it is impossible to investigate radium A chemically, for in three minutes it has half changed into another solid substance, radium B, again giving off helium. This change would be represented by the equation: radium A (218.4) = helium (4) + radium B (214.4). Radium B, again, can hardly be examined chemically, for in twenty-seven minutes it has half changed into radium $C^1$. In this case, however, no helium is evolved; only atoms of negative electricity, to which the name 'electrons' has been given by Dr. Stoney, and these have minute weight, which, although approximately ascertainable, at present has defied direct measurement. Radium $C^1$ has a half-life of 19.5 minutes; too short, again, for chemical investigation; but it changes into radium $C^2$, and in doing so, each atom parts with a helium atom; hence the equation: radium $C^1$ (214.4) = helium (4) + radium $C^2$ (210.4). In 2.5 minutes, radium $C^2$ is half gone, parting with electrons, forming radium D. Radium D gives the chemist a chance, for its half-life is no less than sixteen and a half years. Without parting with anything detectable, radium D passes into radium E, of which the half-life period is five days; and, lastly, radium E changes spontaneously into radium F, the substance to which Madame Curie gave the name 'polonium' in allusion to her native country, Poland. Polonium, in its turn, is half-changed in 140 days with loss of an atom of helium into an unknown metal, supposed to be possibly lead. If that be the case, the equation would run: polonium (210.4) = helium (4) + lead (206.4). But the atomic weight of lead is 207.1, and not 206.4; however, it is possible that the atomic weight of radium is 227.1, and not 226.4. We have another method of approaching the same subject. It is practically certain that the progenitor of radium is uranium; and that the transformation of uranium into radium involves the loss of three alpha particles; that is, of three atoms of helium. The atomic weight of helium may be taken as one of the most certain; it is 3.994, as determined by Mr. Watson, in my laboratories. Three atoms would therefore weigh 11.98, practically 12. There is, however, still some uncertainty in the atomic weight of uranium; Richards and Merigold make it 239.4; but the general mean, calculated by Clarke, is 239.0. Subtracting 12 from these numbers, we have the values 227.0, and 227.4 for the atomic weight of radium. It is yet impossible to draw any certain conclusion. The importance of the work which will enable a definite and sure conclusion to be drawn is this: For the first time, we have accurate knowledge as to the descent of some of the elements. Supposing the atomic weight of uranium to be certainly 239, it may be taken as proved that in losing three atoms of helium, radium is produced, and, if the change consists solely in the loss of the atoms of helium, the atomic weight of radium must necessarily be 227. But it is known that $\beta$-rays, or electrons, are also parted with during this change: and electrons have weight. How many electrons are lost is unknown; therefore, although the weight of an electron is approximately known, it is impossible to say how much to allow for in estimating the atomic weight of radium. But it is possible to solve this question indirectly, by determining exactly the atomic weights of radium and of uranium; the difference between the atomic weight of radium *plus* 12, i. e., plus the weight of three atoms of helium, and that of uranium, will give the weight of the number of electrons which escape. Taking the most probable numbers available, viz., 239.4 for uranium, and 226.8 for radium, and adding 12 to the latter, the weight of the escaping electrons would be 0.6. The correct solution of this problem would in great measure clear up the mystery of the irregularities in the periodic table, and would account for the deviations from Prout's Law, that the atomic weights are multiples of some common factor or factors. I also venture to suggest that it would throw

light on allotropy, which in some cases at least may very well be due to the loss or gain of electrons, accompanied by a positive or negative heat-change. Incidentally, this suggestion would afford places in the periodic table for the somewhat overwhelming number of pseudo-elements, the existence of which is made practically certain by the disintegration hypothesis. Of the twenty-six elements derived from uranium, thorium, and actinium, ten, which are formed by the emission of electrons alone, may be regarded as allotropes or pseudo-elements; this leaves sixteen, for which sixteen or seventeen gaps would appear to be available in the periodic table, provided the reasonable supposition be made that a second change in the length of the periods has taken place. It is above all things certain that it would be a fatal mistake to regard the existence of such elements as irreconcilable with the periodic arrangement, which has rendered to systematic chemistry such signal service in the past.

"Attention has repeatedly been drawn to the enormous quantity of energy stored up in radium and its descendants. That in its emanation, niton, is such that if what it parts with as heat during its disintegration were available, it would be equal to three and a half million times the energy available by the explosion of an equal volume of detonating gas—a mixture of one volume of oxygen with two volumes of hydrogen. The major part of this energy comes apparently, from the expulsion of particles (that is, of atoms of helium) with enormous velocity. It is easy to convey an idea of this magnitude in a form more realizable, by giving it a somewhat mechanical turn. Suppose that the energy in a ton of radium could be utilized in thirty years, instead of being evolved at its invariable slow rate of 1,760 years for half-disintegration, it would suffice to propel a ship of 15,000 tons, with engines of 15,000 horse-power, at the rate of 15 knots an hour, for thirty years—practically the lifetime of the ship. To do this actually requires a million and a half tons of coal. It is easily seen that the virtue of the energy of the radium consists in the small weight in which it is contained; in other words, the radium-energy is in an enormously concentrated form. I have attempted to apply the energy contained in niton to various purposes; it decomposes water, ammonia, hydrogen chloride, and carbon dioxide, each into its constituents; further experiments on its action on salts of copper appeared to show that the metal copper was converted partially into lithium, a metal of the sodium column, and similar experiments, of which there is not time to speak, indicate that thorium, zirconium, titanium, and silicon are degraded into carbon; for solutions of compounds of these, mixed with niton, invariably generated carbon dioxide; while cerium, silver, mercury, and some other metals gave none. One can imagine the very atoms themselves, exposed to bombardment by enormously quickly moving helium atoms, failing to withstand the impacts. Indeed, the argument *a priori* is a strong one; if we know for certain that radium and its descendants decompose spontaneously, evolving energy, why should not other more stable elements decompose when subjected to enormous strains? This leads to the speculation whether, if elements are capable of disintegration, the world may not have at its disposal a hitherto unsuspected source of energy. If radium were to evolve its stored-up energy at the same rate that gun-cotton does, we should have an undreamed-of explosive; could we control the rate we should have a useful and potent source of energy, provided always that a sufficient supply of radium were forthcoming. But the supply is certainly a very limited one; and it can be safely affirmed that the production will never surpass half an ounce a year. If, however, the elements which we have been used to consider as permanent are capable of changing with evolution of energy, if some form of catalyzer could be discovered which would usefully increase their almost inconceivably slow rate of change, then it is not too much to say that the whole future of our race would be altered.

"The whole progress of the human race has indeed been due to individual members discovering means of concentrating energy, and of transforming one form into another. The carnivorous animals strike with their paws and crush with their teeth; the first man who aided his arm with a stick in striking a blow discovered how to concentrate his small supply of kinetic energy; the first man who used a spear found that its sharp point in motion represented a still more concentrated form; the arrow was a further advance, for the spear was then propelled by mechanical means; the bolt of the crossbow, the bullet shot forth by compressed hot gas, first derived from black powder, later, from high explosives; all these represent progress. To take another sequence: the preparation of oxygen by Priestley applied energy to oxide of mercury in the form of heat; Davy improved on this when he concentrated electrical energy into the tip of a thin wire by aid of a powerful battery, and isolated potassium and sodium. Great progress has been made during the past century in effecting the conversion of one form of energy into others, with as little useless expenditure as possible. Let me illustrate by examples: A good steam-engine converts about one-eighth of the potential energy of the fuel into useful work; seven-eighths are lost as unused heat and useless friction. A good gas-engine utilizes more than one-third of the total energy in the gaseous fuel; two-thirds are uneconomically expended. This is a universal proposition; in order to effect the conversion from one form of energy into another, some energy must be expended uneconomically. If A is the total energy which it is required to convert; if B is the energy into which it is desired to convert A; then a certain amount of energy, C, must be expended to effect the conversion. In short, A = B + C. It is eminently desirable to keep C, the useless expenditure, as small as possible; it can never equal zero, but it can be made small. The ratio of C to B (the economic coefficient) should therefore be as large as is attainable. The middle of the nineteenth century will always be noted as the beginning of the golden age of science; the epoch when great generalizations were made, of the highest importance on all sides, philosophical, economic, and scientific. Carnot, Clausius, Helmholtz, Julius Robert Mayer abroad, and the Thomsons, Lord Kelvin and his brother James, Rankine, Tait, Joule, Clerk Maxwell, and many others at home, laid the foundations on which the splendid structure has been erected. That the latent energy of fuel can be converted into energy of motion by



By courtesy of the *London Graphic*.

SIR WILLIAM RAMSAY, K.C.B., F.R.S.

means of the steam-engine is what we owe to Newcomen and Watt; that the kinetic energy of the flywheel can be transformed into electrical energy was due to Faraday, and to him, too, we are indebted for the reconversion of electrical energy into mechanical work; and it is this power of work which gives us leisure, and which enables a small country like ours to support the population which inhabits it. I suppose that it will be generally granted that the Commonwealth of Athens attained a high-water mark in literature and thought, which has never yet been surpassed. The reason is not difficult to find; a large proportion of its people had ample leisure, due to ample means; they had time to think, and time to discuss what they thought. How was this achieved? The answer is simple: each Greek freeman had on an average at least five helots who did his bidding, who worked his mines, looked after his farm, and, in short, saved him from manual labor. Now, we in Britain are much better off; the population of the British Isles is in round numbers 45 millions; there are consumed in our factories at least 50 million tons of coal annually, and 'it is generally agreed that the consumption of coal per indicated horse-power per hour is on the average about five pounds.' (Royal Commission on Coal Supplies, Part I.). This gives seven million horse-power per year. How many man-power are equal to a horse-power? I have arrived at an estimate thus: A Bhutanese can carry 230 pounds plus his own weight, in all 400 pounds, up a hill 4,000 feet high in eight hours; this is equivalent to about one-twenty-fifth of a horse-power; seven million horse-power are therefore about 175 million man-power. Taking a family as consisting on the average of five persons, our 45 millions would represent nine million families; and dividing the total man-power by the number of families, we must conclude that each British family has, on the average, nearly twenty 'helots' doing his bidding, instead of the five of the Athenian family. We do not appear, however, to have gained more leisure thereby, but it is this that makes it possible for the British Isles to support the population which it does. We have in this world of ours only a limited supply of stored-up energy; in the British Isles a very limited one—namely, our coalfields. The rate at which this supply is being exhausted has been increasing very steadily for the last forty years. In 1870 110 million tons were mined in Great Britain, and ever since the amount has increased by three and a third million tons a year. The available quantity of coal in the proved coalfields is very nearly 100,000 million tons; it is easy to calculate that if the rate of working increases as it is doing our coal will be completely exhausted in 175 years. But, it will be replied, the rate of increase will slow down. Why? It has shown no sign of slackening during the last forty years. Later, of course, it must slow down, when coal grows dearer owing to approaching exhaustion. It may also be said that 175 years is a long time; why, I myself have seen a man whose father fought in the '45 on the Pretender's side, nearly 170 years ago! In the life of a nation, 175 years is a span. This consumption is still proceeding at an accelerated rate. Between 1905 and 1907 the amount of coal raised in the United Kingdom increased from 236 to 268 million tons, equal to six tons per head of the population, against three and a half tons in Belgium, two and a half tons in Germany, and one ton in France. Our commercial supremacy and our power of competing with other European nations are obviously governed, so far as we can see, by the relative price of coal; and when our prices rise, owing to the approaching exhaustion of our supplies, we may look forward to the near approach of famine and misery. Having been struck some years ago with the optimism of my non-scientific friends as regards our future, I suggested that a committee of the British Science Guild should be formed to investigate our available sources of energy. This Guild is an organization, founded by Sir Norman Lockyer, after his tenure of the presidency of this association, for the purpose of endeavoring to impress on our people and their government the necessity of viewing problems affecting the race and the State from the standpoint of science; and the definition of science in this as in other connections, is simply the acquisition of knowledge, and orderly reasoning on experience already gained, and on experiments capable of being carried out, so as to forecast and control the course of events; and, if possible, to apply this knowledge to the benefit of the human race. The Science Guild has enlisted the services of a number of men, each eminent in his own department, and each has now reported on the particular source of energy of which he has special knowledge. Besides considering the uses of coal and its products, and how they may be more economically employed, in which branches the Hon. Sir Charles Parsons, Mr. Dugald Clerk, Sir Boverton Redwood, Dr. Beilby, Dr. Hele-Shaw, Prof. Vivian Lewes and others have furnished reports, the following sources of energy have been brought under review: The possibility of utilizing the tides; the internal heat of the earth; the winds; solar heat; waterpower; the extension of forests, and the use of wood and peat as fuels; and lastly, the possibility of controlling the undoubted but almost infinitely slow disintegration of the elements, with the view of utilizing their stored-up energy. Suffice it to say that the Hon. R. J. Strutt has shown that in this country at least it would be impracticable to attempt to utilize terrestrial heat from boreholes; others have deduced that the tides, the winds, and waterpower small supplies of energy are no doubt obtainable, but that, in comparison with that derived from the combustion of coal, they are negligible; nothing is to be hoped for from the direct utilization of solar heat in this temperate and uncertain climate; and it would be folly to consider seriously a possible supply of energy in a conceivable acceleration of the liberation of energy by atomic change. It looks utterly improbable, too, that we shall ever be able to utilize the energy due to the revolution of the earth on her axis, or to her proper motion round the sun. Attention should undoubtedly be paid to forestry, and to the utilization of our stores of peat. On the Continent, the forests are largely the property of the State; it is unreasonable, especially in these latter days of uncertain tenure of property, to expect any private owner of land to invest money in schemes which would at best only benefit his descendants, but which, under our present trend of legislation, do not promise even that remote return. Our neighbors and rivals, Germany and France, spend annually £2,200,000 on the conservation and utilization of their forests; the net return is £6,000,000. There is no doubt that we could imitate them with advantage.

# The Effect of Tobacco Smoke on Plants

## All Vegetable Organisms, from Green Plant to Bacillus are Affected

IN our houses, shops and botanical laboratories, plants come so frequently in contact with tobacco smoke that the effect of the smoke upon the plants deserves investigation, especially in view of the fact that the researches of Neljubow, Molisch and others, have proved that traces of illuminating gas in the air of laboratories exert a great influence on the growth of young plants. It appears not improbable that the abnormal variations which plants exhibit in the laboratory may be due partly to the effect of tobacco smoke as well as to that of illuminating gas. Probably the reason why the effect of tobacco smoke has not been thoroughly investigated is to be found in the well known fact that the common practice of fumigating greenhouse plants with tobacco smoke, for

Fig. 4.—Effect of Smoke on Pumpkin Seedlings.

the purpose of destroying aphides, produces no noticeable injury. A small iron stove is filled with twisted plug tobacco, which is burned in such a manner as to produce as much smoke as possible, while the house is tightly closed, so that it becomes thickly filled with tobacco smoke. Prof. Hans Molisch, whose article in *Die Umschau* is here condensed, says that this fumigation was carried on so intensively in his father's greenhouses that he, as a boy, became acquainted with the symptoms of tobacco poisoning before he had smoked his first cigar.

From a long series of experiments on the effect of tobacco smoke upon plants, Prof. Molisch has derived the surprising conclusion that this effect is very great, and that plants are exceedingly sensitive to tobacco smoke. The following examples are cited in proof of this assertion. Very young seedlings of vetch (*Vicia sativa*), about 1/10 inch high, were placed on a piece of tulle, which was stretched over the mouth of a jar so nearly filled with water that most of the roots were immersed, while the stem and seed leaves were above the tulle. A large beaker glass of more than one gallon capacity was inverted over the jar, with its mouth resting on a plate and sealed by a shallow layer of water. The operation of covering the jar with the beaker was conducted in front of an open window, in order to fill the vessel with pure air. The beaker was then slightly tipped and three mouthfuls of tobacco smoke were blown into it through a bent glass tube. Another jar similarly planted and covered, but not smoked, served as an object of comparison. Both beakers with their contents were covered with zinc covers which completely excluded the light, and were kept in the greenhouse at a temperatur of 60 to 65 deg. F. Six days later the two jars presented the appearance shown in Fig. 1, in which the injurious effect of the tobacco smoke is startlingly evident.

The plants in the left hand jar, which had been exposed to the smoke, were greatly stunted and their thick stalks grew obliquely, horizontally, or even downward, while their buds showed scarcely a trace of the red tint of anthocyan which tinged most of the buds of the plants which had grown in pure air. Fig. 2 shows the result of a similar experiment conducted with vetch seedlings growing in pots, the plants exposed to smoke being those in the right-hand pot. In this case the effect of the smoke is very striking, though not so great as in the first experiment. This difference is due to the method of culture. The soil and the porous pot gradually purify the air by absorbing the injurious constituents of the tobacco smoke. At first the stems of the smoked plant become thick and inclined, but after the air has been purified, they grow vertically and become thinner, so that they gradually approximate to the condition of normal plants.

When the seedlings are grown in water a single mouthful of tobacco smoke is sufficient to produce a marked effect and, what is more surprising, if the beaker is filled with tobacco smoke, rinsed with water, allowed to stand 24 hours, and then filled with pure air and inverted over the young plants, an appreciable effect is produced by the vaporization of ingredients of the tobacco smoke which have condensed on the inner surface of the beaker and have not been removed by washing.

Very similar results to those obtained with vetches were obtained with seedlings of peas, pumpkins and beans. Figs. 3, 4, and 5 show the enormous effect upon the growth of these plants.

The experiments show plainly that tobacco smoke greatly diminishes the length and increases the thickness of the stem, and destroys its natural negative geotropism, i. e., its tendency to grow vertically upward. The smoked seedlings often assume a horizontal or inclined position and an appearance quite similar to that observed by Neljubow and Richter in young plants growing in laboratory air.

The effect of laboratory air upon plants has been attributed, probably correctly, to traces of illuminating gas and its products of combustion. Tobacco smoke unquestionably exerts a similar effect and in future experimentation with plants more attention must be paid to this influence. The fact that greenhouse plants are apparently not injured by fumigation is due to the circumstance that the influence of the tobacco smoke is usually exerted only for night, after which the house is thoroughly ventilated, and that the damp walls and soil purify the air by absorbing the smoke.

But in ill-ventilated rooms in which tobacco is often smoked in large quantities, and in which no such rapid absorption takes place, plants must suffer greatly. The peculiar morbid appearance exhibited by plants growing in dwellings, restaurants and shop windows is due partly to darkness, dust, and dryness, and partly to impurities derived from illuminating gas and tobacco smoke.

It is not so easy to determine which constituents of tobacco smoke are injurious as would appear at first glance, for no chemist has yet succeeded in expressing the aroma of a fine cigar in a chemical formula. Our knowledge of the chemistry of tobacco smoke is very defective. We know that the smoke contains nicotine, pyridin bases, hydrocyanic acid, hydrogen sulphide and carbon monoxide, with other ingredients, but the state of combination of the nicotine and the nature of the pyridin bases are not fully understood. As nicotine is characteristic of tobacco smoke and is very poisonous to men and animals, it appeared prob-

Fig. 5.—Effect of Tobacco Smoke on Beans.

able that nicotine was the chief factor of the injurious influence upon plants. Special experiments, however, have shown that nicotine plays no appreciable part in the morbid changes described above, but that these are caused by pyridin, hydrogen sulphide and especially by carbon monoxide. This conclusion is confirmed by the observation that a quite similar effect is produced by the smoke of paper, straw and wood, which contains large quantities of carbon monoxide, but no nicotine.

Tobacco smoke exerts a still more deadly influence upon bacteria, flagellates, infusoria, and other micro-organisms. It is indeed remarkable that among the many hundreds of bacteriological papers which are published annually only one, a short preliminary notice by Tassinari, treats of this subject, so important to medicine and hygiene. Tassinari exposed bacteria to a continuous stream of tobacco smoke for thirty minutes and found that the development of some disease-producing bacteria was thus prevented or retarded. Prof. Morisch devised a cell by means of which the micro-organisms contained in a suspended drop of water can be observed under the microscope while exposed to the direct influence of tobacco smoke. The cell is fumigated only once, at the beginning of the experiment. In these conditions the motions of certain species of amœba begin to flag in from five to ten minutes. The organisms assume a

Fig. 1.—Effect of Tobacco Smoke on Vetches Growing in Water.

Fig. 2.—Effect of Tobacco Smoke on Vetches Growing in Earth.

Fig. 3.—Effect of Tobacco Smoke on Peas.

spherical form, protrude hyaline processes, and finally fall to pieces after about thirty minutes exposure to tobacco smoke. The stemless bell animalcule (*Vorticella*) ceases swimming after fifteen minutes' exposure and continues merely to move its cilia, and it dies in two or three hours. The Paramœcium or ditch water is more resistant and survives eight hours. Of bacteria *Beggiatoa alba* proved especially sensitive to tobacco smoke which killed it in forty minutes. A very active marine species of *Spirillum* was killed in nine hours.

The rapid influence of tobacco smoke on bacteria is especially evident in luminous bacteria. A piece of filter paper three inches square is moistened with a few drops of a strongly luminous bouillon culture of the marine bacterium *Pseudomonas lucifera*. In a dark room the round spot formed by the liquid appears brightly luminous to an eye accustomed to the darkness. If the paper is placed in a glass box containing a little tobacco smoke, and observed in a dark room, the spot usually becomes invisible within less than one minute, although a similar preparation in pure air continues to shine with undiminished brightness for an hour or more. If, immediately after the disappearance of the light, the paper is removed from the smoke box and placed in pure sea water, the luminosity usually returns in a minute or two. In this case the tobacco smoke acts similarly to ether or chloroform, by exerting an immediate and temporary narcotic effect upon the bacteria.

Tobacco smoke was found to kill or injure all kinds of micro-organisms with which Molisch experimented. It is more poisonous to these organisms than to higher plants, which are never killed by it.

These experiments have a certain hygienic interest. If bacteria are so strongly affected by tobacco smoke, the mouth and throat of an inveterate smoker must be thus sterilized to a certain degree, and rooms in which much tobacco is smoked must also be disinfected by the smoke and by the products of combustion which condense on the walls and furniture. This, however, is but a poor consolation for the smoker, in the opinion of Prof. Molisch. For, if the living substance of plants is so strongly affected by very small doses of tobacco smoke it is hardly credible that saturation of the mouth and the organs of respiration with tobaco smoke, continued many years, can be entirely free from injurious effects.

These experiments also demonstrate in a striking manner the exceeding sensitiveness of plants to certain reagents. Usually when we speak of sensitive plants we mean the "sensitive plant" (*Mimosa pudica*), the Venus's fly trap (*Dionaea muscipula*), the tendrils of vines, and a few similar instances. Plants in general appear to be very sluggish and passive; but the more deeply we penetrate into the nature of the plant the more evident does it become that the power of reacting to external influences is a property widely diffused among plants and that the sensitiveness of plants in some cases is astonishingly acute.

# Utilization of Dead Pine Wood in the South

## The Recovery of Turpentine from Logs and Stumps

THE enormous amount of wood that is annually going to waste in the long-leaf pine forests is astounding. Tourists who go South for the winter often stop to consider the wastefulness that is apparent on every side in our southern pineries. If the millions of cords of dead pine wood that are left to decay in the pine forests were utilized and the money kept in the hands of the people and invested in improvements and profitable industries, the beneficial results would accrue to the good of the entire South. If the vast amount of valuable timber that is consumed annually by forest fires was converted into money and placed to the credit of the owners in the banks, it would take only a little while to store up fortunes for the coming generations.

Death Caused by Improper Turpentining.

Cars Loaded with Treated Wood Ready for the Kilns.

General interest has been awakened among all thinking men as to the judicious conservation of natural resources. The South presents a unique field that has not attracted much attention for the dead long-leaf pine timber, which is commonly known as "lightwood," has not until recently been considered valuable except for fuel. The natural maturing and dying of trees, destructive fires which annually sweep through the forests, and the injudicious methods of turpentining are the three factors which are reducing the pine lands of the South to an enormous extent. With the proper control of these forces the quantity of dead wood could be greatly decreased, and the amount which arises from natural causes could be readily utilized in the production of turpentine. In view of the present prices turpentine can be distilled very profitably from the dead pine wood. The wasteful methods now in vogue for gathering turpentine from longleaf and slash pines are the chief causes for deadening annually millions of trees that would otherwise attain merchantable proportions. Fire kills equally as many trees every year, so that the amount of lightwood in the southern pine forests is almost beyond calculation. In parts of Florida and Georgia it is estimated that five cords of rich, well-preserved lightwood can be gathered per acre. In the State of Florida alone it is believed by men familiar with the conditions that five million cords of dead wood is available, exclusive of the stumps which yield more turpentine than the wood of trunks and branches. There are approximately two million cords of stumps which could be utilized very profitably under conservative forest management.

If all the available dead wood together with the stumps on cut-over lands were judiciously treated for the turpentine which it contains the wasteful methods of tapping live trees could be abandoned until the young trees have attained merchantable sizes. As it is at present the turpentine operators tap all trees 4 inches and over in diameter 6 inches above the ground. After the smaller trees have been hacked and bled they will soon succumb to fire, wind and disease, thus robbing the future generations of what justly belongs to them. Millions of dollars worth of timber are destroyed annually, simply because the turpentine men choose to tap the immature trees for the sake of the small amount of turpentine which can be obtained from them, irrespective of what such trees would yield at maturity. Of the long list of valuable materials now grossly wasted in this country, our turpentine producing pines are perhaps among the most valuable and at the same time the greatest prey for the unscientific turpentine operators.

A demonstration of yielding turpentine from dead wood was made by Dr. Heber, of the Heber Turpentine Company, Jacksonville, Florida, and from one cord of lightwood weighing 3,800 pounds, 12 gallons of turpentine were obtained. A cord of wood obtained from stumps, which weighs about 5,000 pounds, yields from 14 to 16 gallons of turpentine. Dr. Heber was the first man to put into operation a flue system, of uniformly heating a large quantity of wood to drive off the turpentine without the use of steam. His great hobby for many years has been a study of the best and most inexpensive methods of obtaining the best grade of spirits of turpentine from dead pine wood. He has more technical information that can be readily applied in practical distillation and in all matters pertaining to the utilization of the dead wood of the South, than probably any other man in America. Dr. Heber said that the pure spirits of turpentine obtained from dead pine wood when properly distilled has a market value of only five cents per gallon less than that obtained from the resin of tapped trees. If, on an average, one cord of dead wood produces only ten gallons of turpentine, the amount possible to be obtained from the dead pine wood including stumps in the State of Florida alone is about seventy million gallons. At an average of only seventy cents per gallon it would amount to forty-nine million dollars, which is a very conservative estimate. Thousands of cords of pine wood rich in turpentine decay or are consumed by fire annually and are totally lost to man.

Deadening Caused by Wind and Fire.

Not only is the wood valuable for the turpentine it yields, but it may be utilized after the turpentine has been given off for making charcoal, tar, and other by-products.

### Precaution in Making Litharge-Glycerine Cement

ONE of the most useful of the common cements is the well-known litharge-glycerine cement, which when properly made is waterproof and very strong. Precaution should be taken that the ingredients are free from water, however, to insure success. Before mixing a batch, mix up a small pellet and lay it aside to harden. If it does not harden in fifteen to twenty minutes, the probability is that the litharge is damp or the glycerine contains some free water, or both. The litharge should be carefully dried at a low temperature and the glycerine heated over a slow fire until the water is driven off. The litharge and glycerine should be thoroughly mixed, using as little glycerine as possible to thoroughly incorporate, and then add glycerine until the required plasticity is attained.

Timber That Is Over-Mature.

# Problems in Telephone Traffic Engineering—I*

## Some of the Difficulties That Arise in Serving a Heterogeneous Territory

By F. P. Valentine

IT is the purpose of this paper to deal with a few of the many operating problems that confront a telephone company, serving a territory made up of several hundred communities of varying types ranging from a large metropolitan area to sparsely settled rural districts.

A telephone company has but one line of goods to sell, i. e., service. The entire capital investment in telephone plant and all running expenses are for the purpose of handling the telephone traffic of its subscribers or customers, and from this service is derived the revenue of the company.

Under the prevailing form of telephone operating organization, the responsibility for handling the telephone traffic devolves upon the Traffic Department, which usually represents about one-half the employees and pay-roll expense of a telephone company.

In carrying out its duties, the traffic department has a two-fold responsibility; first, to the subscribers for the quality of the service that it renders to them; second, to the stockholders and subscribers for the economy with which it renders such service.

The quality of the service is directly dependent upon the effective application of suitable methods of operation. The effective application of suitable methods also bears directly upon the economy, for only by the use of such methods is it possible to obtain the maximum efficiency of force and plant. Further, both the quality and economy of service bear directly upon the satisfaction of the telephone user or customer. The quality should be such as to meet every reasonable requirement; the economy such as to enable the company to supply service to its customers at lowest possible rates compatible with a reasonable return on the investment, in order to encourage increase in subscriber development, thus constantly enhancing the value of the service to the individual subscriber.

To meet these requirements it is essential that a traffic department should have, in addition to a proper administrative force, an efficient traffic engineering staff. As the work of this staff is what might be termed the production engineering of the telephone business, it is obvious that it requires a qualitative and quantitative analysis of all factors in any way related to the production of telephone service.

The principal factors entering into the production of telephone service, which must be the subject of engineering study, are as follows:

1. Quality of service.
2. Efficiency of labor.
3. Efficiency of operating methods.
4. Production of efficiency of central office equipment.
5. Production efficiency of trunk and toll circuits.

The following discussion of certain phases of traffic engineering problems, in the order above indicated, is based upon some of the results of studies made in the territory of the New England Telephone & Telegraph Company, as it is with the work in this territory that the writer is most familiar. This engineering work, however, is a part of and is carried on in conjunction with that of the engineering staff of the American Telephone & Telegraph Company, for the purpose of making comprehensive fundamental studies.

### QUALITY OF SERVICE.

From the standpoint of the telephone user, the essential qualities of telephone service are accuracy, speed of connection, and uniformity in both speed and methods of handling calls. These requirements are equally essential from the standpoint of the telephone company. Accuracy and speed of connection mean a minimum of waste effort, motion and time. Uniformity in speed and in the method of handling calls trains the telephone user to co-operate with the operator to the same end, with the resultant effect of satisfaction to the telephone user in smooth, speedy service, and for the company a maximum production efficiency by the operating force and an economical use of switchboard equipment.

As the result of constant study there has been developed a systematic method of service inspection which is now practically standardized among the larger operating companies. By means of suitable apparatus, observations are made on every step in the handling of a telephone call. By the use of stop watches the time intervals of each step in the operation are accurately observed and a code record made, sufficiently comprehensive to permit the analysis of the tabulated results of these observations. A sufficient number of calls is observed during the hours of regular traffic to insure the results being representative of the general grade of service being given in the office under observation. This service observation is practically continuous in all large exchange districts.

Equally careful analysis is made of the phraseology used by the operator in dealing with the subscriber. This latter is no small factor in accurate and speedy service. A telephone operator has to handle calls from subscribers of all types and characteristics and under all conditions. Every word and phrase used by the operator in dealing with a subscriber is the result of long and careful study and is designed to convey essential and significant information or direction in the briefest possible form.

Another record essential to the analysis of service quality is what is termed the "record of service criticisms." This is especially valuable as it furnishes a record of the subscribers' opinions of the quality of service.

This is a record not only of all formal complaints which are received, but also of data collected by all supervising employees in the central offices who have occasion to deal with any subscriber in connection with an abnormal telephone call. The record is made by noting in code, on a proper form, any comments received indicating the fact and nature of any unsatisfactory service that the subscriber has had,

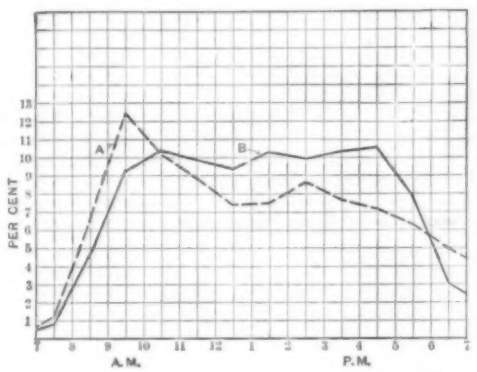



Fig. 1.—Actual Distribution of Traffic in Two Offices for the Day Hours.

either then or at some previous time. Everyone of these cases is followed up and before the record is filed for summarizing, the reasons for the unsatisfactory condition are entered thereon. Besides affording an opportunity to adjust matters to the satisfaction of the subscribers, the analysis of these criticisms furnishes valuable data as to the most frequent causes of unfavorable opinion of service quality, and affords the opportunity of eliminating or minimizing these causes. It is of the utmost importance, not only as good business policy, but also to assist in the analysis of service quality, that every effort be made to obtain fair criticisms from the viewpoint of the customer.

Continuous study and analysis of the results of service observations together with the data obtained from the record of criticisms, has made possible the adoption of standard operating methods designed to give satisfactory service. All calls of abnormal type involving special handling, are transferred to special operators whose sole duty is to care for this class of traffic. This results in removing the most disturbing elements from the work of the "A" or subscribers' operators, and in providing special attention for such calls on the part of employees especially trained for that work.

The adoption of standard methods of operation and the setting of standards of speed and accuracy, has made it possible to reduce all operating procedure to standard sets of instructions for the guidance of all employees concerned. The tabulated results of service observations furnish the administrative force with the information as to how nearly the standards are attained, while the instructions furnish information as to how to attain them.

### EFFICIENCY OF LABOR.

In determining the efficiency of labor, or the production efficiency of an operating force, it is necessary that standards of labor production be established, and that provision be made for significant reports or summaries which will indicate how nearly these standards are approached. It is not sufficient merely to compare results in various exchanges or in the same exchange at different times on the basis of the traffic handled regardless of the conditions attendant upon its handling.

Such a comparison assumes to set as a standard the operation in some particular case. It assumes that at some other place or time an operation was performed with greater efficiency, and, therefore, it should be performed here or now at the same efficiency regardless of whether it is exactly the same proposition in both places or at both times.

The operation of a telephone switchboard comprehends the handling of many different kinds of traffic, and a separate standard is required for the handling of each. To express the degree of efficiency attained as a per cent of these various standards would not only be an interminable task but would give so many individual results that their study and co-relation would be impracticable.

It is necessary, therefore, that a method be employed which in a single percentage figure will show the degree of efficiency attained. This result is accomplished in the following way:

All calls handled are expressed as though they had been of a single class. This is done by multiplying the number of calls of each class by a factor representing the ratio of the labor of handling the calls of a particular class to the labor of handling calls of the class selected as the unit class.

The standard number of these unit calls which should be handled being determined, the per cent of efficiency is readily obtained by comparing the results obtained with those specified as a standard. From the foregoing, it will be seen that this method involves not only the selection of some unit, but the determination of the number of unit calls and the number of calls of other types that may be handled by average skilled operators within a given period, and the establishment of coefficients representing the ratio of the loads of each type of call to that of the unit class.

A flat rate non-trunked call handled on a No. 1 relay board was selected as the unit call for two reasons. It is a very simple type of call and one which predominates in number in most offices. Furthermore, it is of such a class of call that the number an operator can handle depends primarily upon her ability, and not upon circuit conditions.

The determination of the number of unit calls and the number of calls of other classes that operators could handle, involved a most exhaustive study of operating loads. This study consumed a period of over two years during which many thousands of observations were made covering all types of calls, normal and abnormal, from all classes of service. As a result of this study, it was found that an average skilled operator, working in a team of five or more operators, could carry 230 unit calls per hour and maintain that rate during the entire working day, without undue physical or nervous strain, at the same time giving a standard quality of service. Furthermore it was found that, for a single hour in each half day period an operator could, without material impairment of the service, handle 25 per cent more than this number. Even this load could be exceeded at times of unusually sharp peaks.

The ability of the force to carry the peaks at loads in excess of the average busy hour loads, is an important factor in determining operating force requirements. Fig. 1 shows in percentages the actual distribution of traffic in two offices for the day hours. The curve marked *A* is that of an office of the best type of residential subscribers, while the curve marked *B* is that of an exclusively business office. The operators at *A* can carry the busy hour traffic at loads exceeding those of the average busy hours, while the operators at *B* will carry the standard load. With an equal amount of daily traffic in both offices, the same number of operators will handle the busy hour traffic of *A* as are required to handle the busy hour traffic of *B*.

In the evolution of this system of equating calls covering two years of exhaustive study and some four years of practical application, its value and accuracy have been thoroughly tested. Its value lies not only in the fact that it furnishes a means of measuring the efficiency of labor, and is essential in measuring the efficiency of some of the other four factors mentioned in opening this discussion, but in the fact that

* Published in Proceedings of American Institute of Electrical Engineers.

it has opened the way to a most exhaustive analytical study of the human element upon which telephone operation is so dependent.

As a result of the establishment of standards of service quality and labor efficiency, it has been possible to institute methods of selecting and training an operating force with a degree of success otherwise impossible. The question of fitness is of primary importance and the matter of intelligent selection of operators is the result of many years of careful study of the qualities essential to success. All accepted candidates for operating positions are required to spend one month in the operators' training school, listening to lectures in regard to the handling of all types of calls, with the necessary study and examination hours, and in practical operating work under capable instructors on a regular working switchboard representing a typical central office, the calls being originated by instructors. No operator is allowed to work at a central office and handle the calls of telephone users until she has graduated from the school course and met a certain standard of requirement. With this training she has a thorough knowledge of how all classes of calls should be handled and only needs experience to settle that knowledge and acquire speed. This same course of training in modified form, is carried on in the smaller central offices where it is not economical to maintain a regular operators' school.

On an average it takes about a year for an operator to attain maximum efficiency. In view of the fact that, as in any large body of employees, there are constantly resignations and occasionally dismissals for cause, together with the steady growth in subscribers and traffic, it is obvious that the problem of maintaining at all times an adequate and suitably trained operating force, is a very important one. Even with the most constant care in selection incompetency will develop in a certain percentage of the cases either during the school training course, or later, in the work in the central offices. On account of the reasons enumerated, it has been found that in order to produce a force of one year's average experience it has been necessary to start and partially train, or train and keep in service for a short period only, at least three for every one who stayed a year. As it costs over $200,000 per year to train central office operators in the territory of the New England Telephone and Telegraph Company, it is obvious that this is a problem well worthy of careful study.

In order to meet this problem, all conditions of employment and work have received most critical analysis. The operating loads have been most carefully determined having in mind the physical well being of an operating force. Working conditions have been made as pleasant and comfortable as possible. In addition to a liberal lunch hour, a fifteen-minute relief period is insisted upon in the midst of each half day period. Commodious and tastefully furnished rest rooms are provided, magazines and periodicals supplied, and everything possible done to make the work attractive and free from excessive nervous strain. Vacations, with pay, are allowed once during each calendar year. To further the careful study of working conditions and of the human element as it enters into the problem, for over two years the New England Company has employed a physician of highest standing to make a special study of all phases of these conditions.

A careful record is kept of each employee from the time she enters the service of the company to the time she leaves. This record shows the character of the employee's work, comments of her superiors, results of service observations, and every detail that has a bearing on her efficiency. Such a record is essential in the determination of proper wage increases, and the record of reasons for resignation or dismissal is of especial value in the study of ways and means of maintaining a stable operating force.

This carefully studied system of selection, training, and caring for employees, with adequate compensation for efficient work, based solely on merit, has had good results, as is indicated by the fact that during the past four years, it has been possible to increase the average length of employment of the operating forces by 20 per cent, while there is always a waiting list from which to select candidates. It would seem obvious, therefore, that as a large factor in the efficiency of labor the study of the development and maintenance of a proper operating force is essential.

EFFICIENCY OF OPERATING METHODS.

The efficiency of operating methods is in their adaptability to produce the required quality of service with the minimum of effort, labor and operating time per call, together with an economical use of switchboards, trunk and toll circuits.

The methods of handling local calls have been fairly uniform for a number of years, the greatest improvements having been made in specializing the operation for irregular calls, or those which cannot be completed at once by the *A* or subscriber's operator. Another step toward the application of efficient operating methods, brought about by the careful study of recent years, is the gradual elimination or diminution of abnormal types of service, such as heavily loaded party lines in congested centers, etc., which tend to degrade the quality and economy of service.

In the field of toll service, except in a few notable instances, progress was not as great up until comparatively recently. Toll services must be considered in two classes—"short-haul," or suburban toll, and "long-haul," or "long distance" toll. Within a comparatively short radius of most large telephonic centers are usually found a number of smaller communities closely related to the large center and with one another in a business and a social way. The telephone traffic between such offices is of the class first mentioned and usually constitutes a very substantial portion of the toll business, the traffic to more distant points, covered by the second class mentioned, being in the minority.

Toll operating methods have been the subject of most critical analysis for the past few years, resulting in the standardization of several different types of toll operation, each designed to be applied under given conditions.

The subject of operating methods is so fundamental to efficient operation in all its phases that it has received and is receiving very comprehensive study. Every suggestion must receive most careful and critical consideration in order to detect any inherent weakness and to guard against the introduction of a method which, while apparently harmless and even efficient under existing conditions, might fail to meet the requirements of a constantly increasing traffic.

So far as concerns the production efficiency of various operating methods, the use of the unit system, hereinbefore outlined, provided a means of determining the relative efficiency of the different methods. The effect of any change from one method to another can be predetermined by the application of the proper coefficients to the traffic involved.

PRODUCTION EFFICIENCY OF CENTRAL OFFICE EQUIPMENT.

The amount of central office equipment necessary is directly dependent upon the number of equated or unit calls to be handled during the average busy hours, or, in other words, upon the number of employees for whom it is necessary to provide switchboard positions during the average busy hours. With service of standard quality, labor production at standard efficiency, and efficient operating methods, by use of the unit system applied to the amount of traffic to be handled, the switchboard requirements can be accurately determined. The discussion of operators' loads and Fig. 1 in the preceding page apply also to the determination of amount of switchboard.

In engineering central office equipment it is customary to engineer on a basis of a fifteen to twenty year ultimate capacity and to install initial equipment sufficient to cover from two and one-half to three years' growth. As it is necessary to know the ultimate requirements for buildings, etc., these are developed through special studies or "fundamental plans" which include the consideration of all factors that have a bearing on the future development. In order to determine the probable growth in subscribers, it is necessary to maintain curves of growth for past years for each class of service sold. These curves are projected to the ultimate period, and corrected periodically from actual growth. With the curves of station growth is maintained a curve of the station calling rate in each class of service. From these records, supplemented by the yearly estimates of growth, can be determined the number of stations, and volume and type of traffic to be expected at any future period. By application of the equating process to the various classes of traffic and obtaining the number of unit calls to be handled, it is possible to forecast accurately the amount of switchboard required.

The production efficiency of central office equipment is determined by the output per position, or per dollar of investment. The unit system furnishes means of determining the relative efficiency of different types of switchboard for handling particular classes of service under given conditions. Given the desired standard quality of service, the poduction capacity of a given switchboard unit of any type can be predetermined, and actual results attained can be checked, by the proper use of the unit system. The relative economy of different types of boards must be balanced against other costs incidental to the case under consideration.

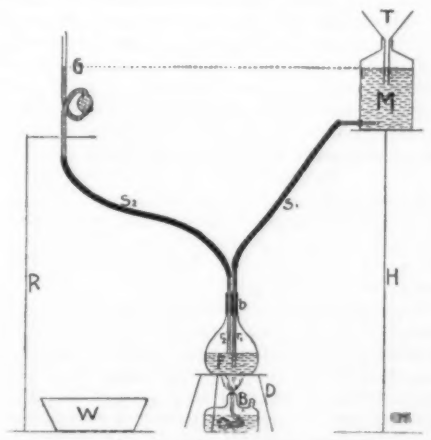
(To be continued.)

## A Model Geyser

THE accompanying illustration, which is taken from *Kosmos*, shows an apparatus by means of which the phenomena presented by geysers can be readily reproduced on a small scale in the laboratory. The apparatus almost explains itself. A flask *F* is placed upon a tripod *D* under which a spirit lamp or Bunsen burner *B* is set. The neck of the flask is closed by a doubly perforated rubber bung *b*. Through one hole there is inserted a glass tube $r_1$, which, together with a rubber tube $s_1$, connects the bottom of the flask *F* with a tubulated bottle *M* placed at a higher level upon a suitable stand *H*. Through the second perforation of the stopper *b* a glass tube is passed, reaching down somewhat less deeper than $r_1$. A rubber tube $s_2$ connects $r_2$ with a glass tube *G*, which is bent into a loop and expanded into a bulb at the center of the loop. The end of *G* is drawn out into a point, and is kept at a level at least as high as *M* by means of a retort stand *R*. Under *G* a catch basin *W* is placed.

To start the apparatus working, *M* is filled with water. This flows through $r_1$ to *F*, partially filling the flask, while the air escapes through $r_2$ and *G*. When *F* is so far filled with water that $r_2$ dips below the surface, the water will rise in $r_2$ and *G*, until it reaches the level of the water in *M*. The burner *B* is then lighted and the water in the flask *F* is boiled.

The boiling water in *F* develops steam, and the air in the flask is also expanded through heat. The gas pressure which is thus produced in *F* forces the column of liquid in $r_2$ out through the tip of *G*. The water which issues is caught in the basin *W*. At the same time the effect of the gas pressure in *F* is to prevent any water from flowing down into the flask from *M*. When all the water, however, has been driven out of $r_2$ and *G*, the compressed air and steam escape through *G*, thus relieving the pressure in *F*. Cold




Apparatus for Demonstrating the Geyser Effect in the Laboratory.

water now flows down from *M* into *F*. The boiling water is thus cooled and the steam condensed. Since practically all the air has been expelled from *F*, the flask at this stage in the process becomes filled nearly to the neck. The water rises in $r_2$ and *G* to the same level as in *M*. Presently the water in the flask is once more brought to a boil. The steam pressure generated forces the water from *F* upward into *M* and *G*. When $r_2$ no longer dips into the boiling water, the steam forces the hot water in $r_2$ and *G* out of *F*. There is thus formed a hot fountain which rises higher and higher, until after a few seconds it suddenly breaks down. It is followed by a hissing jet of steam. The steam pressure is relieved, and water again collects in *F* and *M*; the process just described begins anew and continues indefinitely so long as *M* is kept replenished with water through the funnel *T*.

This experiment represents a geyser on a small scale. In nature *F* would be a cavity in the earth, to which water penetrates from the sea or from a river on the earth's surface, through a fissure (corresponding to $r_1$). The burner *B* corresponds to the earth's hot interior. The hot water and steam are forced upwards through another fissure (corresponding to $r_2$ and *G*), and form a geyser at the earth's surface.

**Diminutive Electric Drills.**—There are small electric drills, which derive their power from incandescent lamps circuits. These drills are readily carried about by hand, and in order to operate them it is only necessary to unscrew a lamp and screw on in its place the connecting nut which sends the current through a portable wire to the drill. With drills varying in diameter from 4 to 18 millimeters, and revolving from 1,300 to 1,800 turns per minute, a power of 80 to 300 watts may be used, with currents up to 250 volts. Larger drills, with slower revolution, require from 180 to 1,150 watts of electric power.

# The Gyro Compass

## Its Principle and Construction

THERE is perhaps no phenomenon in mechanics more puzzling to the uninitiated, than the behavior of the spinning top, or, as it is known in its most highly refined form, the gyroscope. It possesses a peculiar stability which at first sight seems to utterly defy the action of gravitation, and which immediately

Fig. 1.—The Gyrostatic Top. A Simple Toy Which Serves to Illustrate Some of the Properties of the Gyroscope.

suggests to the practical mind a number of useful applications. Among these perhaps the most frequently discussed is the use of the gyroscope for stabilizing various kinds of craft, whether submarine or ordinary vessels, mono-railways or flying machines. There is however another field in which the gyroscope is qualified to render excellent service, namely in navigation, where it not only replaces the ordinary magnetic compass, but is in many respects much superior to that instrument. Especially on the modern warship, carrying immense masses of moving steel, the proper adjustment of a magnetic compass is a most perplexing problem. The gyro compass on the other hand remains of course quite indifferent to any changes in the magnetic conditions of the ship; its independence of magnetism brings with it another advantage, in that the gyro can be made to point due north and south, while of course the magnet needle indicates the position, not of the true poles, but of the magnetic poles, thus necessitating a correction for "magnetic declination." Still another advantage is the greatly increased directional force—the gyro compass is held in its N-S position with a force fifteen times as great as a corresponding magnetic compass.

Let us briefly review the principal facts relating to the gyroscope, and then see how use is made of them in the construction of the gyro-compass. The motion and action of the gyroscope is most easily studied by means of the gyrostatic top illustration in Fig. 1, which can be purchased anywhere.

If the top be held as shown in Fig. 1 with the thumb under one center screw and the first finger over the other, and a good spin be given to the wheel, it will be felt immediately that the top offers considerable resistance to any attempt to turn its axle from its original position, while it exerts a pressure as if

Fig. 2.—Downward Pressure Exerted by the Pencil Causes Precession in the Direction of the White Arrow.

it wanted to twist itself out of the hand. On closer observation it will be seen that the axle always tries to move at right angles to the force used to turn it, and this motion is called "precession."

It will be observed, on experiment, that, if the axis is merely moved parallel to itself, no resistance at all is offered by the gyrostat.

In the following illustrations, Figs. 2 to 6, the direction of rotation of the gyro wheel is the same in all cases.

In all the illustrations straight arrows are used to indicate the direction in which a force is applied to tilt the gyro, while curved arrows indicate the consequent precession.

Figs. 2 and 3 illustrate the direction in which a gyrostat precesses when an attempt is made to turn its axle from its original position. In Fig. 2 the force to tilt the axle is shown as applied with a pencil, and in Fig. 3 a weight is shown hanging from one end of the axle of the well-known Wheatstone compound gyrostat, used for lecture-room demonstrations.

It must be remembered all through the consideration of the action of the gyro compass that precession continues all the time a force is applied to tilt the axle, and ceases as soon as the force no longer acts.

In order to make a description of the Anschütz gyro compass really intelligible, the reasons for the existence of a directive force must be explained first of all.

Foucault's theory contains the general statement that "Every free rotating body, when subjected to some other or new turning force, tends to set its axis of rotation parallel to the new axis of rotation by the shortest path, so that the two rotations take place in the same direction."

It is this principle which governs the practical working of the gyro compass.

In the gyro compass, it should first be understood

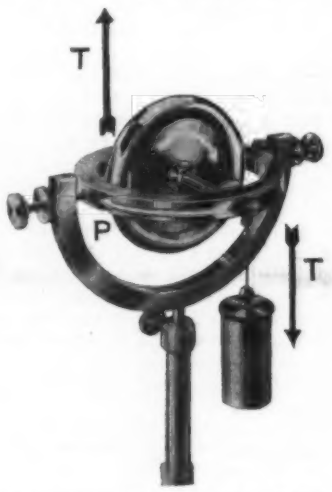



Fig. 3.—The Downward Pull of the Weight Causes Precession in the Direction of the Horizontal Arrow.

that the gyro itself is carried upon a float free to move in a bowl of mercury, so designed that, as long as the gyro is not rotating, the whole moving system is free to swing in every direction like a pendulum. See Fig. 10.

The center of gravity of this whole moving system is below the metacenter.

The gyro is mounted at the lowest point of the moving system with its axle horizontal, and it therefore would swing back to this horizontal position if disturbed and then left to itself; that is to say, while the gyro is not rotating the force of gravity always keeps the axle of the gyro horizontal, and therefore the float and compass card, which are rigidly connected to it, take a corresponding position.

The illustration, Fig. 7, is intended to explain general principles.

The sphere represents the earth as seen from above the North Pole, and a gyrostat is supposed to be rotating at the equator in the direction indicated by the arrow on its periphery.

When the gyro is at position *A*, its axle is horizontal and stands east and west. If, after a certain interval of time, the earth has rotated until the gyro is at the position $A_1$, then, in the case of a gyro with three degrees of freedom, *i.e.*, uniformly suspended and *free to turn in all directions*, the axis would no longer be horizontal as regards the surface of the earth, but the condition would be as shown in the figure at $A_1$, the gyro having kept its axle parallel to the original position which it occupied when at *A*, or in other words, the dark end of the axle would have dipped downward from the horizontal position.

As explained above, however, the gyro compass is not free to turn in all directions, but is acted upon by the force of gravity, which tends to keep the axle horizontal; and this action we may describe as a "couple," represented by the two straight arrows *B* and *C*; under the influence of this the gyro "precesses" in the direction of the curved arrow *D* (see notes on Precessional Motion, Figs. 3 and 4), the effect produced being exactly similar to that obtained by depressing one end of the gyrostatic top, Fig. 2.

Fig. 4.—Illustrating Precession in Direction Opposite to that of Fig. 3.

The direction of this precession will continue the same until a condition is arrived at when the action of gravity has no further pendulum effect on the suspended system, which clearly is when the axle of the gyro is again horizontal. This happens in the following way: In Fig. 7 the rotation of the earth is causing the dark end to dip downward; when, however, the axle swings through the meridian, it will be seen that the earth's rotation causes the dark end to dip downward; when, however, the axle swings through the meridian, it will be seen that the earth's rotation causes the dark end to begin to rise, and thus the axle becomes eventually again horizontal at the same angle from the meridian on the new side as it started at originally on the old side, viz., 90 degrees.

When the axle is horizontal, the precession, or swing to or from the meridian, comes to an end, and in all cases where this occurs (except when the axle is horizontal in the meridian plane) the action of gravity begins to tilt the axle of the gyrostat in the reverse direction, thus reversing the direction of the precession and causing the moving system to swing back towards the meridian again.

The existence of such directive force can only be observed when the speed of rotation of the gyro is high, and all precautions for the elimination of friction are taken; under ordinary conditions, with small models, the directive force must be taken for granted, as it is too small in amount to be easily observed.

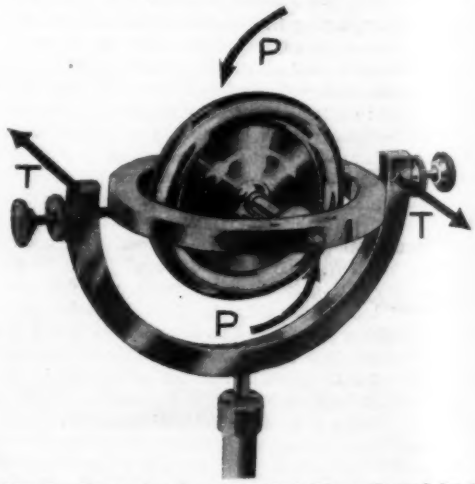



Fig. 5.—Precession in a Vertical Plane Caused by a Force Applied in the Horizontal Plane.

If now the gyro in Fig. 7 be considered on some parallel of latitude other than the equator, as illustrated at *J*, in Fig. 8, the force of gravity keeps the axis of rotation of the gyro horizontal on the earth's surface, and turned into the meridian line by the action of the directive force described above.

For the purpose of illustrating the influence of the earth's rotation on a gyro, the model shown in Fig.

9 has been constructed. The large ring *A* can turn on the base *B* and is intended to represent a meridian line on the globe.

*C* is a small gyro which has inside it a three-phase motor, *D* is a motor generator for converting continuous current into three-phase for the gyro, and *KK* are small springs intended to represent the force of gravity of the model globe.

When the springs *K* are detached from the small ring *G*, the arrangement represents a gyro with three

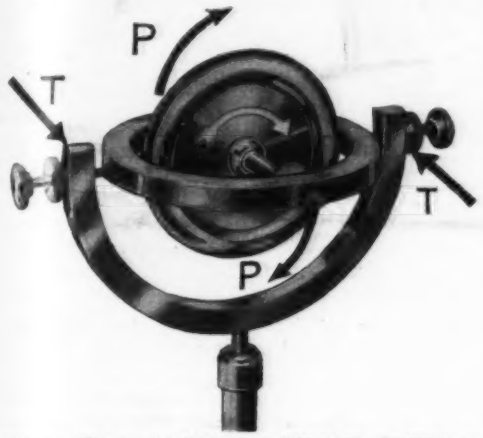



Fig. 6.—Forces Applied in a Direction Contrary to that of Fig. 5 Produces Opposite Precession.

degrees of freedom, for the gyro can be turned in any one of three directions:—

1. Round its axis of rotation, or axle.
2. About a perpendicular axis, because the ring *E* can turn in the foot *F*.
3. About an axis at right angles to the gyro axle, because the ring *G* which carries the gyro is mounted on pivots.

If now the gyro is set in motion by supplying its motor with electric current it will be noticed that turning the meridian ring *A* has only a very small effect upon the gyro (due to the friction of the bearings), and that the gyro axle always continues to point approximately toward the selfsame part of the room.

Now stop the rotation of the gyro, and attach the two springs *K;* then one degree of freedom is suppressed, and the gyro has only two degrees of freedom; the springs themselves represent the effect of gravity, which in the gyro compass tends to keep the gyro axle horizontal, as explained above.

As the effect of gravity is toward the center of the earth, so the springs on the model pull toward the center of the meridian ring *A*, and keep the gyro axis horizontal as regards the model globe (or tangential to the ring's periphery).

Now if the gyro be set rotating and a slow turning motion imparted by hand to the ring *A*, we shall see at once that the gyro, under these conditions, after a few swings to and fro, sets its rotation axis parallel to the meridian ring of our model.

Fig. 7.—Diagram Illustrating the Effect of Gravity at the Equator in Causing the Gyroscope to Precess Until Its Axis Is in the Meridian.

Until the ring *A* is turned, no tendency exists for the axis to set itself round.

The foot *F* can be adjusted to any position round the ring *A* and clamped there by screw *L*, so that the gyro can be placed at any desired "latitude," and the diminution of the directive force can be observed when the poles are approached.

As soon as it is understood that the axis of rotation of a revolving gyro, when correctly suspended, possesses a directive force due to the earth's rotation, in some respects analagous to the magnetic needle, the various points in the diagram (Fig. 10) can easily be followed. This diagram shows a vertical section through the center of the gyro compass as constructed for use on board ship.

In Fig. 10 the case *B* carrying the bearings of the gyro *A* is supported by means of a stalk below the float *S*, which consists of a circular hollow steel ring attached to a dome shaped upper part. This floats in the circular bowl *K* also made of steel and filled with mercury as at *Q*.

Rigidly attached to the float *S* and the gyro *A* is the compass card *R*, which therefore follows all the movements of float and gyro; the axle of the gyro is directly under the north and south line on the card.

Through the glass *G* on the top of the instrument, the divisions round the compass card *R* can be seen, and also the lubber line; a small spirit level mounted on the card makes it possible for any tilting of the axis of rotation of the gyro from the horizontal to be observed.

The whole mercury bowl *K* is carried on gymbals in the well-known manner, and the outer gymbal ring is borne by springs from the binnacle case, so that it is to a great extent protected from damage due to violent shocks; as far as the gymbals and methods of suspension are concerned, these do not differ materially from the design of any ordinary magnetic compass, and one might almost describe the gyro compass as a "liquid compass" in which the magnetic needle is replaced by a revolving gyro with its axle always pointing true north and south.

In order to keep the whole floating system central a steel stem *ST* is fixed centrally in the top glass *G*, and the lower end of the stem dips into a small mer-

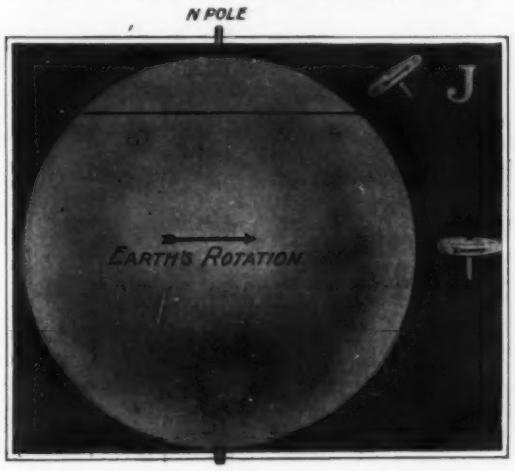



Fig. 8.—Diagram Illustrating the Action of the Gyroscope Compass at Same Latitude North of the Equator.

cury cup carried on the top of the float. A similar connection is effected by a steel tube mounted concentrically with the stem *ST* and a second mercury cup. These two sets of connections are electrically insulated from one another and from the general metal portions of the apparatus.

These two connections carry two phases of a three-phase current to the motor of the gyro; the third phase reaches the motor through the mercury bowl, mercury and float. On this account, the whole instrument is insulated from the binnacle, first by insulation at the gymbal supports, and, as a further safeguard, by insulating supports for the suspension springs where these are secured to the binnacle.

The motor of the gyro is not shown in Fig. 10, but consists of a very small three-phase motor, the stator of which carries the windings, and is mounted inside the case B, so that all the connections can be rigidly made. The rotor is rigidly fixed into the inside of the gyro flywheel itself.

The speed of rotation of the gyro should be about 20,000 revolutions per minute. It is constructed, spindle and all, from one solid piece of special nickel steel, so that there is no chance of anything working loose. The axle is provided with ball bearings made of a specially hard steel, so as to withstand wear for long periods of time; allowance is made for expansion due to heat, and means are provided for replacing all parts of the bearings if required.

The axle of the gyro is of the De Laval type, or a "flexible axis," so that the center of gravity of the whole rotating mass coincides with the rotation axis as soon as a certain critical speed is exceeded. Even though the axle is relatively weak, the gyro, while running, is not sensitive to shocks, because while even the very shortest possible shock lasts the gyro has made several revolutions (333 per second) and therefore any bending tendencies neutralize one another.

To enable the gyro compass to give accurate results in practice, very special attention has been given to every detail of construction, the very highest possible accuracy being necessary in the manufacture of all parts. Many of these parts are of intricate form and

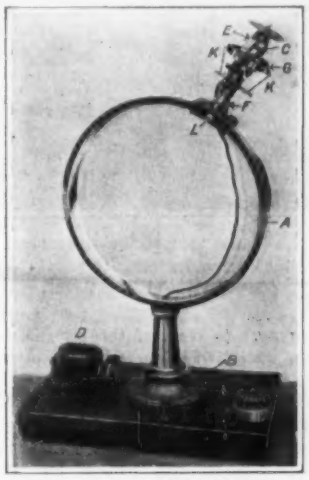



Fig. 9.—Demonstration Model Representing the Earth and a Gyro Compass.

have to be specially constructed with a minimum of weight.

Considering the gyro itself, it is obvious, on account of the high speed (20,000 R.P.M.) at which this revolves, that very special conditions arise, and enormous centrifugal forces have to be dealt with; the stress to which the rim is subjected amounting to some 10 tons per square inch.

A very special steel is employed to insure a sufficiently high factor of safety, to insure that sufficient margin exists, and it may be of interest to state that an experimental gyro was run up far above its normal speed, until it eventually gave way.

To obtain this experimental result a great many special arrangements had to be made. The gyro was run in a vacuum, as otherwise, on account of the air friction increasing with the square of the speed, too much power would have been required, and, further, a special motor generator had to be built to give the enormously increased periodicity necessary for the enormous rate of speed.

Fig. 12 illustrates the gyro at the end of the experiments. The case twisted, but not torn apart. The case checked the rotation of the gyro as soon as it touched. It was found that some five times the normal power had to be applied; this in itself is a proof that no yielding of the material employed can take place in practice, as the motor generator installed cannot give sufficient output to cause so high a speed.

The peripheral speed of the gyro, at its normal rate, is 500 feet per second, or 340 miles per hour; the air friction is so great that 95 per cent of the work done by the gyro motor is absorbed in this manner, and a curious result follows—that the surface of a gyro which has run a few thousand hours is noticeably smoother than when it left the finishing process in the grinding machine before being put into use. There is no doubt that this polishing is due to the actual air friction on the steel itself.

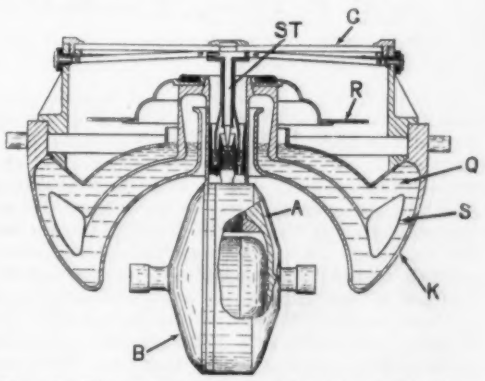



Fig. 10.—View of the Essential Parts of the Gyro Compass.

The ball bearings, upon which the shaft of the gyro runs, require the most minute attention in their construction; the balls have to be gauged to almost inconceivably small limits, and special precision appliances have been devised to examine the spherical condition of the balls.

The gyro motor itself calls for electrical work of

quite a special order. No motor was available commercially which could run 20,000 revolutions per minute, and to get such a machine into the very small space available without undue heating presented a very difficult problem. No idea can be formed, when

Fig. 11.—Principal Parts of Gyro Compass: Mercury Bowl, Floating System, Gyro (in Foreground), and Top Cover.

the finished gyro is seen, of the immense number of experiments which were necessary to bring its practical details to a satisfactory state of perfection. Among other points, the usually accepted text-book figures for the constants of the iron in the motor no longer held good with a periodicity as high as 333 alternations.

While the gyro compass is superior to the magnetic compass in requiring no correction for the influence of masses of iron and for declination, certain corrections must be applied, which however are comparatively slight, for the effect of changes in latitude and of the ship's own movement. There is no difficulty in making these corrections when the ship's course is known.

The best location for the gyro compass is low down in the ships, at some well protected point. Such an arrangement would in itself be extremely inconvenient or quite impracticable, but for the fact that the gyro adapts itself perfectly to a system of electrical transmission from a master compass to any number of subsidiary indicating instrument (repeaters). This is the method actually adopted. The appearance of the dial of one of the repeaters is shown in Fig. 13.

An improvement, in some respects, upon the Anschütz gyro compass, is an instrument constructed by Mr. Elmer A. Sperry, of New York. This inventor avoids the use of mercury, which is troublesome owing to its proneness to "sickening," i. e., becoming coated with a film of oxide, and also in other ways. The Sperry compass is rotated at a much lower speed than the Anschütz, namely 6,000 revolutions per minute, as against 20,000. This reduces very considerable the mechanical difficulties of construction and working. The Sperry rotor is 12 inches in diameter, and weighs 30 pounds. It is further claimed for the Sperry compass, that it equires no correction for change latitude or in the ship's course.

Two interesting sea trials of the Sperry gyroscope compass have taken place this spring. One was conducted on the "Princess Anne," a boat of 2,200 tons, belonging to the fleet of the Old Dominion Line plying between the ports of New York and Norfolk, Newport News and Old Point, Virginia. The other was an official government test on the S. S. Destroyer "Drayton" by the Bureau of Navigation of the United States Navy, headed by the noted compass expert, Lieut. Com. J. H. Sypher.

The gyro compass test on the "Princess Anne" was a duration test lasting five days, from April 21 to 26 inclusive. The gyro was started at noon on Friday, the 21st, and ran continuously for 120 hours until noon of Wednesday, the 26th, when it was shut down. The tests were conducted in the presence of John Bliss, of John Bliss & Company, New York city, who are the compass adjusters of the port of New York. About 100 sun readings were made during the voyage.

The master compass, with its motor generator, was stationed in the steering engine room of the vessel, two decks below the bridge, and the repeating compass was placed in a tripod a few feet astern of the ship's standard, or magnetic, compass on the bridge. The master and repeater were connected by wire cable—ordinary lamp cord.

The current driving the gyro was turned off by accident on the evening of the 24th, and it had been off about twenty minutes before this was discovered. It was turned on again, but the speed of the compass wheel had been reduced only slightly, and the directive power had not been noticeably impaired. Should the power be turned off the gyro compass running at the speed of 6,000 revolutions per minute, it would take several hours before the wheel would come to a standstill when the case is vacuous.

Fig. 12.—Gyro After the Test to Determine Its Breaking Limit.

The course of the vessel lay between magnetic variations of about 9 on the north to 4 7/10 on the south end of the course. The magnetic compass, during the voyage south, was seen to close in gradually, bringing this needle more nearly in line with the readings of the gyroscope compass, and on the return course, the magnetic needle pulled away from the readings of the gyro compass. This observation aroused great interest among those present.

No difference in the work of the compass was noticed throughout the trial. Its running at the end of the trip was similar to that at the beginning, and one could not observe any noticeable change in the

Fig. 13.—General Appearance of Receiver With Central Compass Card.

faint musical sound produced by the instrument during the journey. The bearings—the rotor runs on ball bearings—seemed to run at normal temperature without the slightest change. Practically all the sun readings that were taken were well within the degree. The officers read immediately upon tying up, or as soon after swinging into dock as an accurate reading could be obtained. This almost invariably showed the gyro to be persisting absolutely upon the meridian.

During the trip the compass was subjected to almost every test that an instrument of this kind could encounter on a voyage at sea. The boat rolled considerably, its period being about ten or twelve seconds. Several rolls were about 40 degrees, but these motions of the vessel seemed to have no effect upon the operation of the compass.

While the "Princess Anne" was swinging in the harbor of Newport News with a big hauser at the prow and propeller reversed, there were various resonant points reached in the period of the spring of the boat, when the vessel shook vigorously. Commander A. M. Cook of the Ordnance Bureau observed this and told the men about him that this vigorous shaking was a great deal more severe on the compass than heavy gun fire would have been on a battleship with the compass in or near the engine room. Still these motions appeared to have no effect upon the gyro compass or its accuracy. During the course the little wheel maintained a speed of only 6,000 revolution per minute and developed all the directive power that was necessary to hold both master and repeating compasses practically absolutely upon the meridian.

For our illustrations and much of the information here given we are indebted to a booklet published by the manufacturers of the Anschütz gyro compass.

# The Great Star Map—IV*

## Star Positions

By H. H. Turner, DSc., D. C. L., F. R. S., Savilian Professor of Astronomy in the University of Oxford

Continued from Supplement No. 1863, page 179.

In the last article it was shown that from the mere counting of the stars (taking note of their brightness) it is possible to infer some important facts about the nature of the universe in which we are placed: such as the existence of a cluster of stars to which our sun belongs; and the existence of an extremely tenuous "fog" in the depths of space. But we can always learn much more from prolonged inspection than from a mere glance. A single photograph of a scene tells us only the actual situation at a given moment. It may suggest that changes are going on; but to be sure of these changes we must have another photograph taken later; and if we can get a whole series taken consecutively, as in a kinematograph, we may get a complete history of the changes. The Great Star Map in process of construction is only the first picture; others must follow it if we are to study the motions of the stars, and our knowledge will grow with each repetition. What revelations the future may have in store for us we cannot at present even guess, though it is not too soon to be learning something. The important point to be remembered—and its importance cannot be too strongly emphasized—is that the main purpose of the present project is to provide a basis for these future discoveries, by fixing the present places of the stars with such accuracy that movements can be detected readily. It is only by keeping this fact in mind that we can understand the reasons for the great labor which is being undertaken so cheerfully. A much less laborious project would tell us a great deal; thus nearly all the knowledge about the number of the stars of a given magnitude, which we considered in the last article, could be gathered from photographs taken on a very much smaller scale. There is for instance a very handy map of the complete sky published by the Harvard University Observatory, consisting in all of only fifty five glass plates, each 10 x 12 inches, the whole weight of which is only about 30 pounds, and the price $15 (rather under cost, owing to the liberality of the Observatory). When we compare with this the 22,154 plates of the Great Star Map, weighing three tons, or the two tons of paper which the chart reproductions will represent, it is clear that the discrepancy needs explanation. The explanation is simply that the "Harvard Sky," as it is called, though it will tell us many things, will not allow us to study the changes of the stars *in position*, because the scale is too small. Other changes can be studied with its aid: thus the magnitudes of the stars are shown by it rather better than on the Great Star Map, being more uniform in different parts of the plate; and we can study changes in magnitude by comparing two plates taken at different times. The Harvard Sky is actually being used in this way to discover new variable stars, and a great many discoveries have already been made. A positive copy of one plate is superposed on a negative of the same region taken on a different date, and the sharp eyes of three experienced ladies detect any want of correspondence between the pairs of images. At the end of the year 1909 the examination of twenty-one out of fifty five portions of the whole sky had yielded 211 new variables; and the efficiency of the search, and of the plates of the Harvard Sky as a means of conducting the research, is constantly attested by the rediscovery of known variables in the course of the examination. If changes in brightness of the stars were all that need concern us we need have no map larger in scale than the Harvard Sky, though it would be profitable to use more powerful instruments so as to show fainter stars.

* Reprinted from *Science Progress*.

But it is important, it is indeed of the very greatest importance, to measure also changes in the positions of the stars; for this purpose the Harvard Sky is unsuitable because of its small scale. The places are correct so far as they go, but the residual uncertainty is more than ten times that of the Great Star Map. Consequently, to measure any given change of position we should have to wait at least ten times as long, and since the majority of the changes with which we are concerned may be expected to require a century or more for their complete identification on the plates of the map as planned in 1887, those who made the plans cannot be accused of extravagance or hurry.

The scale of a star map depends essentially on the length of the telescope used in making it. The little instrument with which the Harvard Sky was made is only about a foot long, while those used for the Great Star Map are about 11 feet. The surface of the representation increases, of course, as the square of the linear dimensions, so that we might fairly expect the weight of the plates to be increased in the ratio 121 to 1; and since the plans for the map involve covering the whole sky twice over, we must double this, getting 242. Now the ratio of 3 tons to 30 pounds is 224 to 1, so that the weight is adequately explained by the increase in scale. If we use the same factor (242 or thereabouts) to get an idea of the cost of the plates forming the large map, from the Harvard $15 (which, however, is less than the actual cost of the Harvard Sky, though it is generously offered for sale at this figure), multiplying 15 by 242 we get $3,600 or £700. But the actual cost is greater than this because plate glass has been used and two edges of each plate have been specially ground; probably £1,500 or £2,000 is not too much to put down as the cost of the plates. But this after all is only a very small portion of the real cost of the map, which arises chiefly from the work done on the plates after they have been taken. In order to expedite comparison with other plates to be taken in the future, the present positions of the star images on the plates are being carefully measured and the measures printed. How much shall we set down for this? It is impossible to make an accurate estimate since circumstances vary so much with nationality, but some rough idea may be gathered from the experience of Oxford, where the measures have been made and printed. Even here there are difficulties, as will appear from the following statement of a generously superior limit to the total cost:

TOTAL POSSIBLE COST OF THE OXFORD ASTROGRAPHIC CATALOGUE.

| | |
|---|---|
| Telescope given by Dr. Warren De la Rue..... | £600 |
| Maintenance of University Observatory for twenty years, including assistance..... | 13,000 |
| Salary of professor for twenty years..... | 18,000 |
| Government grant (from the fund administered by Royal Society) in the years 1896-1910.. | 1,200 |
| Printing (shared between the government and the University) ..... | 1,200 |
| Total..... | £34,000 |

The chief difficulty is to determine how much of the two main items, the maintenance of the Observatory and the salary of the director, are to be credited to this particular work. In the above statement the whole of the professor's salary has been set down, not even deducting income tax; but some of it must be credited to teaching and other duties which fall on him as on his colleagues.

The same difficulty arises in a smaller degree about the second item in the list, as the assistants have by no means confined themselves entirely to work on the star map. As the best estimate possible under the circumstances we may take £20,000 perhaps as the Oxford contribution to this great work; and as there are seventeen other contributors, many of whom are not working under such favorable conditions, the total cost will be at least half a million sterling.

These estimates have not been made and quoted for sensational purposes but with the very definite object of showing the necessity for care in procedure. We are dealing with big figures—long periods of time and large sums of money. We must on the one hand spend money freely to save time; we must make a map on a large scale, so that we may determine the movements of the stars within a reasonable period. On the other hand, since every detail of the process will be repeated thousands or even millions of times, we must be extremely careful in settling the details so as to save expense. If one figure will suffice rather than two, the difference may seem trivial in a single instance, but when multiplied a million times will constitute a serious item of unnecessary expenditure. If one measure will give fair accuracy, then before yielding to the temptation to increase the accuracy a little by making a second measure, we must remember that we are multiplying the total cost of measuring by two and consider carefully whether the extra expense is justified; and that we are also multiplying the time required for completing the work by two, and consider carefully whether the completion can be so long delayed without serious disadvantage. When confronted by such problems, the different contributors to the scheme have naturally differed in their solutions. At Oxford we have throughout fixed our attention on getting the work done as quickly and economically as possible, consistently with certain rules laid down by the international committee; nevertheless the work has taken twenty years. Of course with a larger staff the time might have been shortened; and at Greenwich, where the available resources are greater, a more elaborate programme has been completed in a time shorter by a year or so: but nowhere else is the work yet finished, the prospects of completion being in many cases very remote; seeing that at the outset five or ten years was mentioned as the proper time for the work, the present situation gives some cause for anxiety. The fact is that the necessity for strenuous economy in detail has not been sufficiently realized: some of the larger observatories strained at an accuracy scarcely possible even for them; and their weaker brethren, in attempting to copy their example, have been left far behind. Moderation and self-denial are just as necessary in astronomical work as in other walks of life.

Let us consider in detail the nature of the work to be undertaken. The process of measurement of the positions of the star-images on the photographic plates has been much facilitated, as already mentioned, by the impression of a *reseau* on the plates. Two series of equally spaced lines are ruled, one set at right angles to the other, so that the plate is divided up into a number of small squares of exactly the same size. It is necessary to specify what is meant by "exactly" in this connection. Nothing, of course, is really perfect or exact, but for practical purposes we may regard a ruling as exact if the errors are so small as to be negligible in comparison with the accidental errors of measurement. In this sense and for the purposes of the Map we may regard the little *reseau* squares as accurate and exactly equal. If we number them from left to right ($x$) and also from below to above ($y$), then two appropriate numbers ($x$ and $y$) will specify the square in which any star-image lies; and if in addition we measure the distances of the image from the sides of the square, we shall complete the specification of its exact position. The distances are expressed (in the decimal notation) as fractions of the side of a square and written down immediately after the whole numbers specifying the square. There is no difficulty about the whole numbers; the doubtful points all arise in connection with the fractions. It would take too long to consider them all; we take two important ones as illustrations.

Firstly, how often should we recur to the image of a single star? We have to measure two co-ordinates, $x$ and $y$; we may repeat the measures of each: We may do this for each of the two or three images which occur on the plate (according to the plan already explained) and take the mean; and we may then turn the plate round into another position and repeat the measures. (This last precaution will need no explanation to any one who has had experience of such measurement: It detects and eliminates well-known personal peculiarities in the measurer.) It would therefore be easy to adopt a plan of measurement which would involve recurring to the same star $2 \times 2 \times 3 \times 2 = 24$ times, without real superfluity. Indeed, such a process would be definitely advisable for a small piece of work wherein the utmost accuracy was desired. But what we have to settle with regard to the project before us is whether we can afford it. For comparison let us take the minimum instead of the maximum advisable programme: We can measure both co-ordinates of the star at a single setting on a single image, and this would be the actual minimum, but scarcely advisable—or there is nothing to check a mistake. To check mistakes we must have at least another measure; and if we turn the plate round through 180 degrees to make this, we shall at the same time eliminate the personal errors referred to above. This, then, may be taken as the minimum advisable programme; it involves recurring to the same star twice and twice only. It was adopted at Oxford, and the work of measurement took even a dozen years: It will be seen how easily this might have been turned into half a century or more.

The second important question of detail concerns the apparatus for measuring the fractions of a square. That which first occurred to the astronomer was the micrometer screw, with which he was already familiar in work at the telescope; at many observatories this type of instrument has been adopted for use. A spider-line in the microscope is set on the side of the *reseau* square and the reading of the micrometer screw noted: Then the screw is turned until the spider-line falls on the star-image and the reading noted again: Finally the screw is turned further until the spider-line falls on the opposite side of the *reseau* square and the reading noted once more. From these three readings and a little arithmetic the quantity required is deduced. This process can be made very accurate, though there are some difficulties, especially those resulting from gradual wear in the screw when it is used thousands of times. But though accurate, it is very slow. It is far quicker to abolish the screw and substitute a finely divided scale in the field of view of the microscope. It has been shown that the fractions can in this way be read off at sight without losing time in turning a screw. The rapidity of the process naturally excited the suspicion at first that it might be too rough; in order to combat this prejudice, one of the advocates of the new method took over his apparatus to Paris on the occasion of the assembly of 1896 and offered to give a demonstration. A committee was appointed to sit upon him: They shut him in a room with his machine and a plate he had never seen before; he was to produce as many measures as he could in half an hour. At the precise second completing the thirty minutes the door was opened and his measures impounded. It was found that the prisoner had measured twenty-five stars with satisfactory accuracy, and by many this demonstration of the qualities of the machine was accepted as sufficient. With experience a still greater pace can be acquired but we may take fifty stars per hour as a fair average rate for one person (though two people working together can do better). Now it is easy to spend two or three hours on the same fifty stars if we used a screw instead of a scale, so that here again we have a danger of unduly prolonging the work.

The view here expressed that it is stringently necessary to study economy of time and labor is frankly that of an advocate. On the other side there is considerable weight of tradition and opinion which remains unshaken even by such consequences as the great delay in completing what was originally intended to take ten years. Our scientific traditions have come down to us from times when workers were so few and scattered that almost anything they produced, however planned, was precious if not priceless; we see the consequences of this early practice in some huge editions of the correspondence of great scientific workers in which nothing is too commonplace to be included. It is quite possible that considerations of economy have been rightly disregarded in dealing with this sacred past; but does this justify a similar attitude with regard to the future which is better under our control? Scientific workers are no longer few and isolated; they are numerous and they are binding themselves into organizations among which that for making the Great Star Map has an early and an honorable place. It does not seem unreasonable that the changed conditions should leave their mark on the methods of work, and that the relation of cost to value of product should be considered as in other enterprises. In old days the value of the product was so high that any cost could be neglected; and there are still cases where this is the correct view—let us hope there always will be. But in the case of a great piece of straightforward measurement like the Star Map, the value can be expressed very definitely by the "probable error" of the result; and alternative plans for the work can be compared by setting down the probable error and the cost (in time and money) of each. So far as I know, however, this principle has not yet been applied except in a special case in geodesy. It is certainly one that may be applied in other sciences if judged sound; but at present it scarcely seems to have met with the approval, even the attention, of any large body of scientific workers. I trust no apology is needed for inviting attention to it in a scientific review of this kind, even at the expense of a slight digression.

(To be continued.)

**Dynamo Design.**—For a given output, modern dynamos are much smaller than older types. The magnetic flux-density is much higher and so the core losses are greater. The agreement between experiment and calculations as to heat losses has hitherto been far from satisfactory. This is due mainly to the use of erroneous formulæ for the eddy current losses. The author of an article appearing in the columns of a French contemporary shows how simplified approximate formulæ, which are sufficiently accurate for everyday work, can be obtained from advanced theory. He discusses the rate at which the armature loses heat by conduction, radiation, and convection currents. He takes into account the fact that the thermal conductivity of iron varies with its magnetic flux-density. The quantity of heat dissipated is a function of the velocity of the armature. Formulæ are given for the case when the surface is polished and when it is dull. Use is made of several of Fourier's solutions to find the rate at which heat is conducted away in special cases.

# The Hot Air Balloon of the Twentieth Century

## The Revival of the Montgolfier

THE first hot air balloon rose from the earth at Annonay, France, on June 5th, 1783. Although 128 years have passed since the Montgolfier brothers thus put their great invention to a practical test, no improvement has been made in hot air balloons. The hydrogen balloon and the coal-gas balloon were successively invented and developed, and the hot air balloon was neglected and despised. It has seldom been used except for sensational ascensions at fairs.

Fig. 1.—Ascension of a Hot Air Balloon.

The hot air balloon differs from the gas balloon in many ways, and notably in the mode of inflation. The bag has no netting, but its mouth is surrounded by a ring from which the car is suspended. The bag is supported and more or less distended by poles over a fire of straw until it is sufficiently inflated with hot air to rise. If the balloon is held until the air in the bag is very hot it attains great buoyancy and rises very rapidly, but almost instantly reaches its level of equilibrium. The air quickly cools and the balloon sinks as rapidly as it rose. The flight continues for 10 to 20 minutes and extends to a distance of 3 to 12 miles, according to the velocity of the wind.

This limitation in time and distance has prevented the practical development of the hot air balloon. If the buoyancy could be maintained by a source of heat carried by the balloon, the result would be an aerial vehicle superior to the gas balloon. Until recently no such source of heat was practically available, but we now possess an ideal liquid fuel, the kerosene used in lamps, and burners by which it can be completely consumed, with the aid of preliminary vaporization. All that is required is a suitable battery of such burners which will serve both to inflate the balloon before starting and to keep the temperature of the air in the bag constant during the flight.

The following account of the manner in which this problem has been solved in France is furnished by *La Nature*:

The revival of the hot air balloon was vigorously discussed last summer in the columns of the aeronautical journal *Aéro* and a society entitled "La Montgolfière" was formed for the practical study and popularization of the hot air balloon. Before describing the improved balloon and heaters which the society has already devised and constructed and which have proved very satisfactory, we will point out the respective merits and demerits of the gas balloon and the hot air balloon.

The source of heat by which the hot air balloon is inflated is usually left behind on the ground, so that the air in the bag quickly cools and the buoyancy vanishes. The gas balloon starts with an excess of buoyancy compensated by ballast which can be thrown out as the buoyancy diminishes. The improved hot air balloon, carrying heaters, requires no ballast, as the buoyancy needed to maintain equilibrium at any altitude can always be supplied by the heaters, and the balloon can be caused to ascend or descend by increasing or diminishing the supply of heat.

The gas balloon has several important defects. The bag is filled with an inflammable gas which may explode at any instant; the reserve buoyancy is limited to the weight of ballast that it is practicable to carry; the inflation is costly and can be accomplished only in the vicinity of gas works. The perfected hot air balloon is free from these defects, for it cannot explode, requires no ballast and can be inflated anywhere very quickly and cheaply.

The heater devised by the society "La Montgolfière" is illustrated in Fig. 2. A circle of burners *B* is supplied with kerosene under pressure from the reservoir *C*. Each burner, *A*, consists of two U-shaped tubes *c* one of which is set cross-wise within the other, and which are connected at their upper ends by a cross-shaped tube *d*. The bottom of the outer W-tube is attached by a perforated screw-plug *a* to the ring-shaped pipe which supports and supplies all

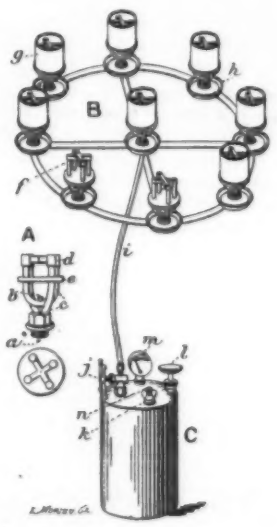



Fig. 2.—Kerosene Heater and Reservoir for Hot Air Balloon.

of the burners. The kerosene, entering through this plug, rises in the legs of the outer W-tube, and flows through the tube *d* to the legs of the inner W-tube, down which it passes to their junction, where it issues as vapor from a minute jet *b*, and burns with a blue flame, of intensity proportional to the pressure in the reservoir. As the tubes of the burner are entirely immersed in the flame, the kerosene is completely volatilized. When the pressure is taken off, the kerosene in the burner flows back into the reservoir and the flame is extinguished. The burner is surrounded by a short chimney, attached to the support

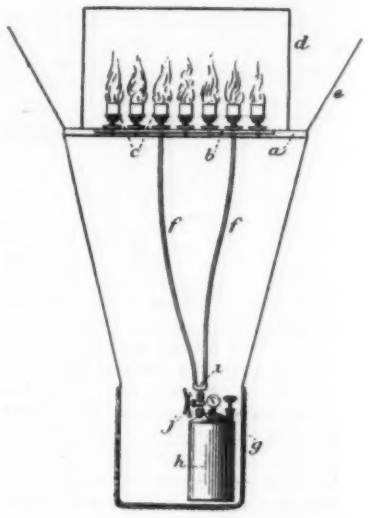



Fig. 3.—Arrangement of the Apparatus in the Balloon.

*c*, for the purpose of confining and directing the flame and the hot products of combustion. At the base of each burner is a cup *h* in which a little alcohol or gasoline is ignited for the purpose of heating the tubes and vaporizing the kerosene at the beginning. The diagram (Fig. 2) shows only 9 of the 20 burners which are actually used. Some of these *g* are shown with their chimneys, others *f* with the chimneys removed. The kerosene rises through the tube *i* from the reservoir *C*, where it is subjected to pressure created by the air pump *I* and controlled by the gage *m*. The flow is regulated by the stop-cock *j*, and the pressure is taken off by opening the vent *n* in the stopper *k* of the hole by which the reservoir is filled.

The arrangement of the apparatus in the balloon is shown in Fig. 3. The reservoir *h* is placed in the car and the circle of burners *bc* is attached to the ring *a* which distends the neck of the bag, at a height of 6 or 7 feet above the floor of the car. The burners are connected with the reservoir by one or more flexible tubes. The diagram shows two tubes *ff*, each of which supplies half of the burners, and which communicate with a double stop cock *L*, by means of which half of the burners can be extinguished without extinguishing the rest. A single stop-cock is indicated also. The arrangement can be varied indefinitely, and each burner may have a separate supply tube and stop-cock. The whole ring of burners is inclosed and covered by an envelope *d* of fine wire gauze or asbestos cloth to prevent the possibility of flame reaching the skin of the balloon *e*.

In the course of the present year these improved self-heating hot air balloons will doubtless be seen in operation, and aeronauts will be enabled to make many ascensions and long aerial voyages with comparatively little expense.

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### International Language and Patents

A LECTURE which Prof. Ostwald delivered at Bonn early this year has just been published in pamphlet form, and we take occasion to note in particular the reference made therein to the question of an international language in its relation to patent affairs. Ostwald's enthusiastic support of the movement for an international language, for which he has made propaganda with his usual vigor and originality, is well known to all, and it is with the greatest interest that we listen to his remarks on the advantages of an international language in the transaction of patent business. Ostwald observes that with the present system, in which repeated translation and re-translation is necessary for the purpose of securing patent protection in the several civilized countries, it is almost impossible to assure with perfect certainty, that the invention is completely and exactly covered by the specification and claims. Hence it insures that matters of the highest interest, representing often many millions of dollars in value, are exposed to the accidents and frailties of a more or less successful translation.

When once we have an international language, the inventor himself will be in a position to express his ideas in a form which will be both intelligible and binding internationally.

While the position which Ostwald takes in this matter is on the whole convincing enough, nevertheless the question suggests itself whether after all the benefit derived will be quite as complete as expected. For there will be at least one translation required, namely, into the international language, and as yet we have no guarantee that an artificial language can ever be commanded by any person with the same perfection, as his natural mother-tongue, or even perhaps an acquired natural language. Furthermore, we have been impressed at different times with the fact that there are apt to be dissensions in the camp of Esperantists, Idoists and so forth. These circumstances seem hardly altogether calculated to reassure us in our faith in the international language as a help in patent practice. This remark is made, not with any desire to disparage progressive endeavors, but merely to draw attention to a point which must not be left out of consideration. If an international language can be introduced with success, there can be no question at all as to the great advantages which will be gained in many fields of commercial activity with its use.

# Loaded Telephone Cables*

## Their Function in Preserving the Wave Form of the Original Message

By Dr. J. A. Fleming, F.R.S., Professor of Electrical Engineering in University College, London

WHEN the telephone was first invented and began to be used, more than thirty years ago, anticipations were indulged that it would be possible to transmit the songs of an operatic prima donna or the speeches of a public orator by submarine cable between Europe and America. But a very little experience showed that severe limitations existed to the transmission of telephonic speech through a cable. The reason for this is the electrostatic capacity of the cable. A copper wire surrounded by gutta-percha or

Fig. 1.—Passing Over the Sheave a Loading Coil in the Anglo-French Telephone (1910) Cable Laid Across the English Channel.

India rubber, and buried in the sea or soil, forms a virtual Leyden jar of large capacity. The electrical capacity of an ordinary Leyden jar, such as is used in wireless telegraphy, may be about one-five-hundredth of a microfarad. The capacity of one mile of submarine cable may be one-third of a microfarad, or nearly one hundred and seventy times as much. Hence even twenty or thirty miles of submarine cable has a very considerable capacity; and the capacity of an Atlantic cable is about eight hundred microfarads, or about the same as the capacity of the whole earth considered as a sphere free in space. The effect of this capacity is that if we attempt to send an electric current through the cable it has (so to speak) to be filled up with electricity before any current begins to flow out at the distant end. Moreover, if we make sudden changes in the strength of the current at the sending end, these changes are not reproduced instantly at the other end, or in the same degree. The mathematical theory shows that the speed with which these current changes travel along the cable depends upon their frequency. Also, the degree to which the amplitude of these changes decreases, or *attenuates*, depends upon their frequency, and upon the constants or structure of the cable. Current changes of high frequency attenuate more rapidly and travel faster than those of low frequency.

Now when an articulate word is spoken to the diaphragm of a telephone transmitter, the rapid changes of air pressure which constitute sound, compress the diaphragm and produce corresponding changes of resistance in the carbon granules of the microphone. These again cause variations of like nature in the electric current entering the cable. These current variations are a more or less complete copy of the air pressure changes. If the cable could transmit these current changes unaltered to the telephone receiver at the other end, speech would be perfectly reproduced. The wave-form, or mode of current variation, which corresponds to articulate speech, is very complicated, but it may be resolved into the sum of a number of vibrations of different frequency and amplitude. The effect of the electrical capacity of the cable, as already mentioned, is to cause an attenuation, or weakening, in the amplitude of the current vibrations as they are transmitted along the cable, and this attenuation affects the higher or shrill notes more than the lower or deep notes. Also the higher notes travel faster than the lower ones. It will easily be seen that the result of this inequality is that the wave-form of the current is *distorted* by transmission. The different constituent notes or harmonic vibrations arrive at the far end of the cable unequally degraded, or attenuated, and shifted in phase relatively with each other, the high vibrations having outrun the lower ones.

If this distortion has not proceeded beyond a certain limit, the ear of the listener is able to guess, from the sound heard, the meaning of the word, just as in the case of bad or ordinary handwriting we are able to guess from the general shape of the written word what it means although the individual letters are badly formed or distorted. If, however, the distortion has proceeded beyond a certain point, then the ear is unable to attach a meaning to the sound heard. Apart, therefore, from any imperfection in the actual telephonic instruments, or in the speech or hearing of the two communicants, we have a limit to the telephonic transmission of speech, imposed by the distortional qualities of the cable itself. Accordingly, it was soon found that the limiting distance of speech through an ordinary submarine telegraph cable might be taken as twenty miles or so, depending on the size of the core. In the case of land, or overhead, lines, this limiting distance is very much larger. The capacity of an overhead line per mile is not a one-hundredth or one two-hundredth of that of a submarine cable, and therefore telephonic speech is possible through several hundred miles of ordinary overhead wire.

The question of the improvement of telephony by underground and underwater cables soon began to be discussed, and foremost among those whose writings assisted in laying the true scientific foundation was Mr. Oliver Heaviside. He showed that the true antidote to the capacity effects of the cable was to add to it inductance. This term may be defined, for the ordinary reader, as follows: A coil of wire, especially a coil of many turns, possesses a property in virtue of which a current started in the wire tends to run on, and also the starting of a current takes time. Inductance, electrically speaking, corresponds to inertia in the case of ordinary matter. Generally speaking, we may say that the presence of inductance hinders rapid changes of currents in a line, just as inertia in machinery hinders very rapid changes of speed in moving parts. For this reason non mathematical electricians of the old school had arrived at the idea that inductance in a telephone line should be reduced as much as possible. On the contrary, Mr. Heaviside showed that what most telephone lines required was not less, but more, inductance, to make them less distortional. In short, inductance is capable of neutralizing capacity in cables. The reason for this is that capacity in cables acts as if it were a sort of vacuum, into which electricity tries to rush just as air rushes into a gaseous vacuum. On the other hand, inductance opposes the movement of electricity and hence inductance in series with capacity can be made, by suitable adjustments, to neutralize each other. The suggestion was therefore made as far back as 1887 that to effect an improvement in the qualities of the line it was necessary to add inductance to it. All problems in engineering are, however, ultimately questions of cost and detail, and until it had been practically shown that this addition of inductance was both economical and advantageous, telephonic engineers were hardly justified in embarking on expensive constructions. In 1899 and 1900, however, Prof. Pupin, in the United States, published the results of some remarkable investigations on this subject. He showed that if coils of wire (called loading coils, see Fig. 1) having high inductance were inserted in the run of a telephone cable at equal distances, and so close that nine or ten of the coils were covered by or included in one wave of the current, the result was as if the inductance were smoothly distributed over the cable and also that provided the inductance were large enough, a considerable improvement in the speech-transmitting qualities resulted. The phrase, wave of current, needs a little explanation. The characteristic of a wave motion of any kind, whether in air or water, is that some change is periodically made in the medium, which is repeated successively at contiguous points. If we have a long cable, at one end of which some kind of periodic or alternating electromotive force is applied, then the changes in potential are not reproduced instantly at all points in this cable, but are propagated from point to point in it with a certain velocity. The more rapid these changes the faster they travel, up to a limiting value which is equal to that of light. At certain points in the cable, separated by distances called one wave-length, changes of potential of similar type take place at the same time; that is to say, the potential becomes zero or a maximum at the same instant. It is found that the mean value of the frequency involved in ordinary speech is nearly eight hundred. That is, the mean pitch of the aerial vibrations has this value.

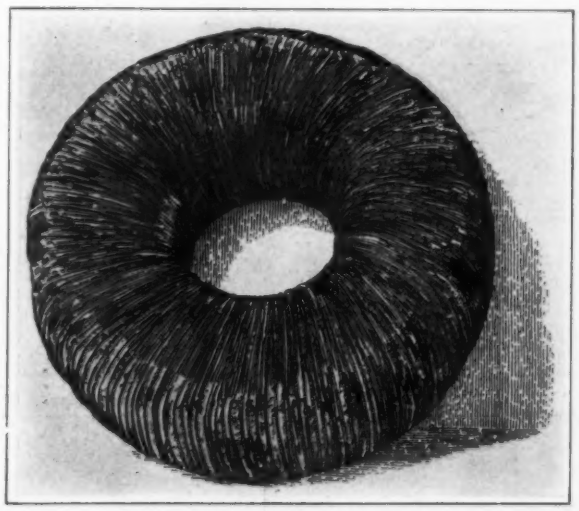


Fig. 3.—A Loading Coil for Loaded Telephone Cables as Used by the National Telephone Company.

Corresponding to this frequency in a telephonic

* Reprinted from *Knowledge*.

cable the wave-length may be ten to twenty miles or so. Now a telephonic or telegraphic cable has four specific qualities. Its conductor has a certain resistance per mile reckoned in ohms, and also a certain inductance measured in units called a henry. Also it has a certain capacity per mile, and a certain leakage per mile.

Mr. Heaviside first showed that to make a cable distortionless in the sense that waves of all frequencies would travel along it at the same rate, it is necessary that the product of the resistance and of the capacity per mile shall be equal to the product of the inductance and leakage per mile.

In all ordinary cables the capacity is too great to fulfill this condition, and hence we have to increase the inductance to approximate to the distortionless condition.

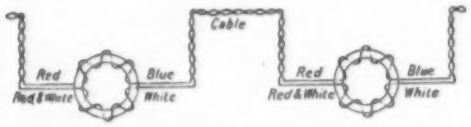



Fig. 2.—Mode of Inserting the Loading Coils in the Two Sides of a Telephone Cable.

Pupin showed that we can add this inductance in lumps, so to speak, provided we insert these lumps of inductance at such intervals that there are nine or ten coils per wave-length at a frequency of eight hundred. A telephone cable so constructed, with inductance coils inserted in it every mile or so, is called a *loaded cable*, and loaded cables have of late years played an important part in improving telephonic communication. After the publication of Pupin's researches attempts were made to put them to practical test in long overhead telephone lines, both in the United States and in Germany. The results were very encouraging, and the attention of telephonic engineers was closely directed to the subject. It is a comparatively easy matter to insert such inductance coils in an overhead line, because they can be attached to the telegraph posts, a coil being inserted in the line circuit every mile or so.

circuits have been much employed of late years by the National Telephone Company (see Fig. 3). A more interesting and recent application is in the case of submarine telephone cables. So inferior is even a length of twenty miles or so of submarine cable to an equal or even much greater length of aerial line in the transmission of telephonic speech, that the great obstacle in conducting telephonic communication with Ireland or the Continent has always been the interposition of the twenty to eighty miles of submarine cable necessary to cross the English or Irish Channel. The problem of loading a submarine cable was, however, one of peculiar difficulty. In any case the laying of an unloaded submarine cable involves engineering difficulties of a considerable kind. Even when the advantages of inserting the loading coils had been well ascertained, cable engineers were rather reluctant to embark on the enterprise of laying a submarine cable having heavy protuberances in it every mile or so. Hence as a first step attempts were made at continuous loading. The inductance of a cable can be increased by winding over it many layers of fine iron wire separated, however, from the copper by an insulation. The effect of this is to increase the magnetic field surrounding the conductor when a current flows through it. Such a continuously loaded cable will be thicker and heavier than an ordinary unloaded cable, but the risks in laying it are not thereby seriously increased. Several continuously-loaded telephone cables were laid in Denmark. There are, however, difficulties in the way of foretelling the actual performance of such a class of cable, which do not exist in the case of cables loaded in the Pupin manner. The first cable of this last type laid under water was that put down a few years ago in Lake Constance. The length of this cable is nine miles and it consists of a paper-insulated lead-covered cable, having loading coils inserted in it at intervals. The performance of this cable was such as to encourage further developments, and a year or so back, when the authorities of the British Postal Telegraph service began to consider the laying of a new telephone cable across the English Channel, the question of a loaded cable was seriously considered. After many experiments and measurements, a type of Pupin-loaded cable was evolved which was made and laid for the Post Office by Messrs. Siemens Brothers, in 1910. This Anglo-French loaded telephone cable was described to the Institution of Electrical Engineers recently in a paper by Major O'Meara, C.M.G., the engineer-in-chief of the British Postal Telegraph Department.



Fig. 5.—Section of Cable Containing Loading Coils, Complete with Sheathing Wires.

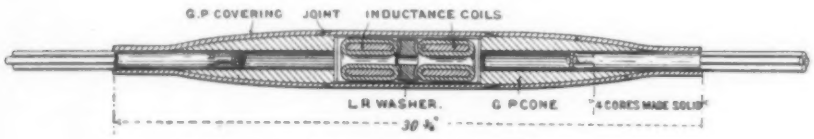



Fig. 6.—Arrangement of Coils in Cable.

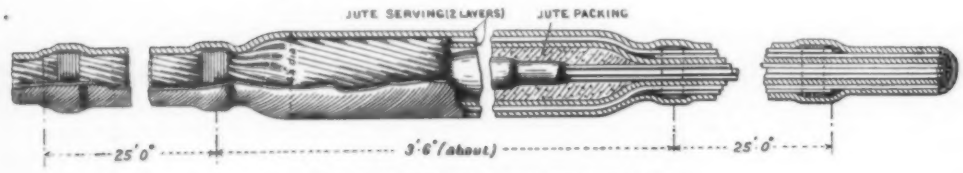



Fig. 7.—Method of Sheathing Over Coils.

The coils used consist of iron rings built up of fine iron wire which are wound over with many turns of silk-covered copper wire like a transformer (see Fig. 2). These loading coils are inclosed in iron cases and fixed on the posts. It is easy to construct such a coil to have an inductance of about 0.1 henry, and a resistance of only ten to fifteen ohms.

Loading coils can also be easily inserted in the run of underground telephone cables, and such loaded every nautical mile, coils are inserted which consist of silk-covered wire wound over an iron core so as to form an inductance coil which is inserted in the run of the cable (see Fig. 5). The gutta percha insula-

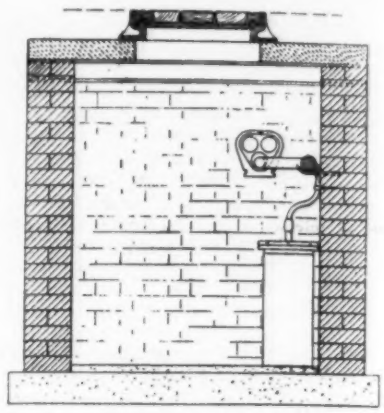


Fig. 4.—A Brick Pit for Containing the Loading Coils Inserted in Telephonic Cables.

tion and the steel wire armoring are, of course, continued over the coil, and the result is to produce an enlargement or protuberance on the cable every mile.

The cable was laid with great skill by the manufacturers at the bottom of the English Channel between Abbots Cliff, near Dover, and Cape Grisnez, in France.

The cable was laid by the cable ship "Faraday" by the experienced operators of Messrs. Siemens Brothers, and under the inspection of officials representing the British and French Telegraph Services, between May 15th and May 18th, 1910. Some special precautions had to be taken in handling the thickened-up portions of the cable containing the loading coils (see Fig. 7). The operations were, however, successfully carried out, and London and Paris are now connected by a new telephone cable of superior type containing two complete circuits. The attenuation constant of the new cable or ratio in which the current is enfeebled in passing along the cable was found to be close to the predicted value, and the speaking qualities of the cable also fully realized expectations. By the employment of extra thick conductors in the land lines at each end, and when the added distances do not exceed seventeen hundred miles, Major O'Meara states in his paper that well maintained conversations by telephone could be conducted between London and Astrakhan on the Caspian Sea. This important achievement has been watched with great interest by practical telephone engineers on both sides of the Atlantic. The great improvement in the distances over which it is possible to speak telephonically through cables when loaded in the Pupin manner is a great testimony to the value of correct scientific theory in guiding practice. The old rule-of-thumb methods are abolished, telephonic engineers are everywhere engaged in studying the improved methods of predicting the effect upon the speaking qualities of certain constructions in telephonic cables which have been based upon the researches of Heaviside and Pupin, and reduced to simplicity chiefly by the work of Dr. Kennelly, of Harvard University, U. S. A.

The writer of this article delivered last year to a large class of practical telephone engineers a course of post-graduate lectures on this subject on behalf of the University of London, and these lectures have just been published by Messrs. Constable & Co., in a book entitled "The Propagation of Electric Currents in Telephone and Telegraph Cables" in which a full discussion of the scientific questions involved in loaded telephone cables is given.

## A German View of Our Panama Canal Worries

THE European public annually receives from America fresh assurances that the Panama Canal will be completed in January, 1915, and it has therefore become accustomed to the thought that this great project, the vain hope of four centuries, will become a reality in four years. On the other hand, many engineers who have followed the progress of the work, or who have visited the Canal Zone, regard the completion of the canal in 1915 as extremely doubtful, if not impossible. It is certain, at least, that the American reports of the smooth and rapid progress of the work are optimistic and do not correspond with the facts, that extraordinary obstacles have been encountered and have not been overcome, that the officials responsible for the canal are beset by worries and fears.

The difficulties which have confronted and will confront the enterprise are of five kinds: sanitary or climatic, technical, geological, financial and commercial . The political difficulties were removed in 1903 by the very opportune secession of Panama from Colombia and the prompt cession of the Canal Zone to the United States by the now and "independent" republic.

Two of the remaining five difficulties have now, in all probability, been overcome. The Americans, who in Havana and elsewhere have proven themselves masters of the art of sanitation, have succeeded at immense cost in surmounting the hygienic and climatic obstacles which nearly prevented the construction of the Panama railway half a century ago. The financial basis of the enterprise, even if it shall cost much more than is now estimated, is also secure, because the completion of the canal is regarded in the United States as a matter of national honor, and almost unlimited funds will be forthcoming, if required. In any event the American Panama canal will not share the fate of its French predecessor.

The technical, commercial and geological difficulties stand on a different footing. It was obvious from the beginning that the hard primary rock of Panama would offer far more serious obstacles to canal cutting than were encountered in the sand of Suez, but this difference is a matter of time and money and is susceptible of fairly accurate calculation. The grave difficulties are those that cannot be computed or foreseen. The construction of the great Gatun dam, in particular, has occasioned much trouble and worry. The purpose of this dam is to retain an ample supply of feed water for the canal, and the dam will be re-

quired to withstand the pressure of an immense volume of water 95 feet in depth. This requirement, which is exceeded in the case of the Assouan dam in Egypt, would present no great technical difficulties in favorable conditions, but the Gatun dam, though it rests in general on a bed of clay, crosses two former channels of the Chagres river which are filled with porous detritus to a depth of 288 feet. No expert knowledge is needed in order to appreciate the insecurity of a dam resting on a foundation which is not watertight. This construction has been much discussed and severely criticized in America.

Col. Goethals, the chief engineer of the canal, and his associates, feel assured of the staunchness of the dam, but the opinion of the unquestionably high authorities is naturally optimistic. The worst feature of the case is the impossibility of justifying this confidence until the dam has been completed and the basin filled, when it will be too late to correct errors in construction. The engineers who were formerly in charge of the work were compelled by the pressure of public opinion to promise that they would strengthen the foundation of the dam by driving piles at the weak spots, but this precaution has been neglected as unnecessary. Even with perfect confidence in the accuracy of the calculations and the examination of specimens of the substratum, this appears like reckless gambling with fate.

Another difficulty, equally important and less dubious, has been encountered in the Culebra cut, where a channel nearly 50 feet deep is being hewn out of the rock. If the cut were entirely in solid rock, the duration and cost of the work could be accurately computed, but the rock is covered, and in places traversed, by sand and clay, which continually slide and often carry the rock with them. In 1885, when DeLesseps was endeavoring to construct the canal, the German engineer Pescheck declared that the practicability of the project depended on the frequency with which these sliding masses of clay, which had already been met with, should be encountered. As a matter of fact, they appear to occur very often. They contributed largely to the failure of the DeLesseps enterprise and they have sorely troubled the American engineers, who have been only partially successful in preventing sliding by steadily diminishing the steepness of the sides of the cut and correspondingly increasing the cost and duration of the work. Moreover, the heavy sliding masses often displace and distort the bed of the canal by their pressure. In one night, in 1887, 100,000 cubic yards of rock were thus precipitated upon the canal bed.

Similar accidents may be expected to occur after the canal is finished and in this way the depth of water in places may be greatly diminished without detection, and vessels may be grounded and seriously injured. These avalanches are greatly promoted by the exceedingly violent rainstorms, or "cloudbursts," which are of frequent occurrence and, although Pescheck's prediction that they would prevent the building of the canal is probably exaggerated, they afford good ground for pessimistic forebodings.

These are not the only technical difficulties. The heavy rains and the floods caused by them sometimes make the most careful and elaborate calculations utterly useless. There is another factor which, although it has not yet created any practical difficulty, may at any time destroy large sections of the canal in a few minutes. This is the circumstance that the isthmus of Panama is not, like that of Suez, entirely immune to damage from earthquakes. It is true that the Panama region is comparatively free from the earthquakes which are of frequent occurrence in Central America and that the Panama canal is much more favorably situated in this respect than the projected Nicaragua canal, which would pass near twenty-five volcanoes, but the Canal Zone is not exempt from seismic disturbance. It experienced a slight shock in 1882 and in the past has been visited by violent and destructive earthquakes, the last of which occurred in 1621. The recurrence of such a visitation, though improbable, is quite within the limits of possibility, and the completed canal, with its insecure and sliding banks, might be utterly destroyed by a single violent shock.

In addition to these and many other technical and geological worries, there is reason for grave misgiving in regard to the commercial future of the canal. It is very doubtful if the Panama canal, even if it is completed within a few years, will become the important artery of commerce and the worthy rival of the Suez Canal that it is designed to be. It comes into the world far too late to render to civilization the service that it might have rendered in the past.

In order to understand this fully, let us suppose that a natural navigable waterway across the Isthmus of Panama had always existed. In this case the history of the world would have been very different. The northeastern part of the Pacific Ocean would not have remained almost unknown until the middle of the nineteenth century, the commerce of Europe with Australia and eastern Asia would have taken the Panama route, from which it could hardly have been diverted by the construction of a Suez Canal, and the tragic three hundred years' search for a northwest and a northeast passage would not have been instituted.

Now, however, although a newly created Panama Canal will be convenient in many ways, it will not be indispensable. The whole development of the present trade routes is based on the absence of a Panama Canal, and railways have made the canal superfluous for many purposes.

If a natural waterway through the Panama isthmus had always existed its importance would have declined steadily during the last forty years. Passengers and mails, even of European origin or distinction, are carried between the Pacific and the Atlantic coasts of North America by the great transcontinental railways of the United States and Canada, and this traffic can no more be diverted to the Panama canal than it can be diverted to the Straits of Magellan. A large part of the Pacific coast of South America is now in the same situation as that of North America, in respect to passenger and mail traffic. The opening of the railway between Buenos Aires and Valparaiso, in 1910, has deprived the Panama canal forever of the greater part of the Chilean traffic of this character. Within another year a railway connecting Buenos Aires with Mollendo, Peru, and traversing Bolivia will be completed and the express traffic of another large section of South America will be lost to the Panama Canal, for the passage through the lock canal will occupy more time than the journey by rail to Buenos Aires and thence by sea to Europe.

In Mexico and Central America, also, new railways have robbed the canal, even before its completion, of most of the passenger and mail traffic. Mexico already has two, and will soon have three, railways extending from ocean to ocean, an interoceanic railway has just been opened in Costa Rica, and others are in process of construction in Honduras, Nicaragua and Guatemala. Although most of these roads will be of inferior character their existence and their number will offer serious competition to the canal, for it is unlikely that many travelers will prefer the long detour through the Panama Canal and the uninviting Caribbean Sea.

Thus the passenger and mail traffic of almost the entire Pacific coast of the American continent with the exception of Colombia, Ecuador and northern Peru, will hold aloof from the Panama Canal, although for a few years a steadily dwindling stream of tourists will be attracted to the canal route by curiosity. The passenger traffic to Australia and New Zealand may be more stimulated by the opening of the canal, than the traffic to the entire west coast of America.

What are the prospects with regard to freight traffic? This prefers the water route and the commerce of Atlantic countries with the Pacific coast of America, especially South America, will certainly be greatly promoted by the opening of the Panama canal. Even in this respect, however, the best time has passed. The tonnage passing through the hypothetical Panama natural waterway would have declined very appreciably in recent decades.

Although, in general, a railway cannot compete successfully with a parallel water route in the carrying of freight, such competition is possible when the land route is very much shorter than the water route. This is illustrated by the history of the Panama isthmus itself. The old Panama Railway which was constructed half a century ago, with an enormous sacrifice of human life, was long successful, despite its defective operation and high freight charges, in diverting a large part of the interoceanic commerce from the sea route by way of the Straits of Magellan. In order to appreciate this fact fully, it must be remembered that half of the cost of carrying a ton of freight from New York to Valparaiso via Panama was paid for the short haul across the isthmus.

This experience warrants the inference that the new interoceanic railways will compete with the canal as successfully as the old Panama Railway competed with the Magellan route. The Tehuantepec Railway of Mexico, extending from Puerto, Mexico, to Salina Cruz, far to the north of Panama, is short and admirably equipped for the convenient, rapid and comparatively cheap transportation of freight from ocean to ocean. This railway, in its present improved form, with its fine new terminal harbors equipped with the latest appliances for rapid loading and unloading, is less than five years old, but it has already attained an importance which is shown by the fact that in 1910 it carried nearly seventy million dollars' worth of freight, while less than thirteen million dollars' worth was carried by the Panama Railway. It appears very doubtful that this preponderance of the Tehuantepec route will be materially diminished by the opening of the Panama Canal.

According to the reports of the United States Department of Commerce, the value of merchandise (in millions of dollars) shipped from American ports via Panama increased from 5.8 in 1905-1906 to 12.8 in 1909-1910. The corresponding figures for Tehuantepec are 11.4 for 5 1/3 months in 1906-1907, and 69.6 in 1909-1910.

Why, indeed, should traffic between New York or Europe and the Pacific coast of North America prefer the long sea route via the Panama canal to the shorter sea and land route via the Tehuantepec Railway? The choice of the Panama route would involve great loss of time and a tedious voyage, unattractive to any seaman, through the Caribbean Sea and the long lock canal, and it would not even save expense, for the cost of the long detour and the necessarily high canal tolls would certainly equal the cost of railway carriage and double trans-shipment at Tehuantepec. Unless the cost of transportation is considerably less via Panama than via Tehuantepec, however, the canal is practically excluded from any share in the commerce of the Pacific coast of North America.

For the canal is left the freight traffic between the eastern United States and Australia and the west coast of South America, together with part of the Central American and, possibly, part of the Asiatic traffic, although the Asiatic trade, in many cases, will certainly prefer the Tehuantepec route, to which it has already become accustomed.

These remarks apply mainly to steamer traffic. It is more difficult to predict the future routes of sailing vessels, but as the canal and its approaches lie in the zone of calms and towing is very expensive, it is very probable that sailing vessels will continue to use the cheap and well-accustomed, though long and dangerous passage around Cape Horn, and will avoid the Panama Canal as they avoid the Suez Canal and the Red Sea, in which also favorable winds are rare.

Another cause of worry, which seems ludicrous but is quite serious, is the lively agitation in Colombia for the construction of a rival canal connecting with the Atrato River which flows into the Gulf of Uraba. This apparently fantastic scheme is daily gaining in popularity and a Colombian engineer recently issued an impassioned appeal to his fellow-countrymen to avenge the loss of Panama by constructing a Colombian rival to the American canal. The importance attached to this project in the United States is shown by the fact that an official protest has already been sent from Washington to Bogota.

Unprejudiced consideration of the points enumerated above must lead to the conclusion that the prospects of the immensely costly Panama canal are not very brilliant, and that the canal cannot, in any event, attain an importance comparable with that of the Suez canal. The strategic value of the Panama canal to the United States, especially in a war with Japan or other western enemy, will unquestionably be great, but even in this respect exaggeration is easy and there are many American strategists who place a very low estimate on the importance of the canal. It will be impossible to move an American fleet from the Atlantic to the Pacific coast via the canal in less than about seventeen days, a much longer time than will be required for a Japanese fleet to cross the Pacific. The existence of the canal, therefore, will not relieve the United States of the necessity of maintaining a Pacific fleet, or greatly diminish the requisite naval strength.

Moreover, the possibility of utilizing the canal in all circumstances in war is by no means assured, despite the great fortifications which the Americans are erecting at a cost of one hundred million dollars, in direct contravention of the Clayton-Bulwer treaty of 1850, which declared the unconditional neutrality of any future isthmian canal. Even if the ends of the canal are protected by impregnable fortifications and guarded by twelve thousand men, how can the fifty-mile long canal be protected from attack and destruction by a hostile force coming by way of the neutral territory which borders the narrow Canal Zone on both sides? David's Bay, near the island of Coiba, would afford a convenient landing place for Japanese troops, and the Japanese showed in 1904, on the Kwantung Peninsula, how coast fortifications, impregnable by sea, can be made useless by a land attack.

Seventeen years ago the eminent economist Schanz characterized the Ludwig Canal, which connects the Rhine and the Danube, in the following language, which applies almost exactly to the Panama canal: "The canal question was agitated during thirty years and then an imperfect and by that time antiquated canal was constructed. . . . The importance of the new modes of transit was not appreciated. A work which fifty or a hundred years ago would have brought much benefit and would have greatly accelerated the commercial development of Bavaria, has now a limited values and is a source of enormous expense." —*Prometheus.*

# The Power of Niagara Falls

## Taking Stock of the Energy Utilized

IN the Engineering Supplement of the *London Times* Dr. J. Winthrop Spencer gives an account of the power situation at Niagara Falls, which is of such interest that we reproduce it here in full:

"The International Boundary at the Falls of Niagara, as established in 1819, is located on the Canadian side of the middle of the river, and passes at a distance of only 300 feet from Goat Island. This location causes almost the whole crest line of the main falls to be within Canadian—that is, British—territory.

LENGTH AND HEIGHT OF THE FALLS.

"The whole length or perimeter of the falls, including the two islands, which interrupt the continuous sheet of water, measured about a mile until it was recently shortened by the diversion of the river, owing to the use of the Queen Victoria Park for the power plants. The perimeter of the main cataract or Canadian falls was 2,950 feet, and the length of the smaller or American falls is still about 1,000 feet. As the channel of this smaller cataract on the east side of Goat Island is both shallower and narrower, only 5 per cent of the volume of the river flows over the American falls, the average depth of the water being less than 18 inches. However, at the head of Goat Island the boundary line is so placed that 20 per cent of the water is on the side of the United States. Thus the waters from the New York side flow over the boundary line into Canada before descending the great cataract. The international line being in unnavigable waters, this was of no importance until the diversion of the river was about to be made. But with the extended utilization of the power, part of the river bed will be laid bare, as already the water has become very shoal in this part of the channel. There is now also a large diversion of water through the great canal at Chicago, the supply being taken from Lake Michigan, which is a tributary of the Niagara drainage. These features affect the engineering problems at the falls themselves.

"At the end of the main cataract, on the Canadian side, the height of the falls is 158 feet, while the American falls are 167 feet. But immediately above the crest lines of both falls there are magnificent rapids descending 55 feet (in the western channel), from over a rock-rim of the basin above Goat Island. These rapids give rise to an important part of the energy at the falls, and raise the gross head of water to 213 feet. This rock-run is higher than the floor of the river at the immediate outlet of Lake Erie, some 20 miles away, and is thus the real rock-sill for the outlet of the lake, so that engineering operations at the falls affect the level of Lake Erie and navigation.

THE POWER PLANTS.

"The two New York companies both take their water by canals leading from the basin mentioned, but by different methods. The first of them constructed a surface canal 4,500 feet long to the brow of the gorge below the falls, so that the water descends directly through the tubes or penstocks to the wheels, a height of 210 feet. The other company sunk a wheelpit, at the bottom of which were placed the turbines. From the wheel-pit a waste-water tunnel was constructed for a distance of 6,500 feet to the river surface in the gorge, some distance below the falls. This was the first construction of its kind at Niagara, and a considerable slope was allowed, so that the velocity of the waste current might compensate for the restricted size of the tunnel; but this arrangement was at the expense of nearly a third of the total head of water, which is thereby lost as power.

"On the Canadian side there are three large plants in operation. Two are situated near the foot of the upper rapids, and thereby lose a head of water amounting to 55 feet. The other plant takes its supply from a point at the rim of the basin above the rapids, and conveys the water through huge tubes for a distance of about two miles to the power-house in the gorge immediately below the falls. As the water rises in water-towers above the wheel-house, there is no loss in the descent of 55 feet in the tubes, other than by friction. All these works on the Canadian side are in the Queen Victoria Park—a national reservation secured through the influence of the late Lord Dufferin, when governor-general of Canada.

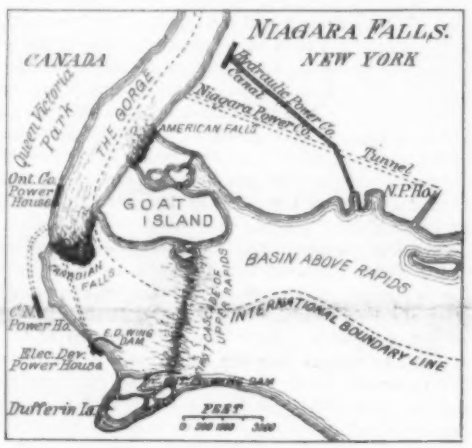
"The lowest plant has only a short waste tunnel; the middle plant has a tunnel of 2,100 feet, which terminates under the falls themselves, and the construction of which was a somewhat difficult engineering feat. The other plant has no waste tunnel, as the power-house is in the gorge.

"The most difficult engineering problem was the building of the great wing dams to draw in the water to the two upper works. In one case 11 acres of the river bed were exposed, at a point where the current was most violent, some 20 miles an hour or more. In order to construct these submerged wing-dams, great coffer-dams were built out, and in one case a double coffer-dam was necessary, since the depth of the current was increased to 27 feet.

"In view of the shoaling of the river, owing to the diversion of the water on the Canadian side, the park commissioners shortened the perimeter of the falls by 415 feet. The effect of the diversion is chiefly due to the water being taken from behind the rim of the basin above the upper rapids, as this rim determines the distribution of the water in the two cataracts, deep water occurring only in part of one of the channels. The effect of diversion upon the level of Lake Erie also arises from the water being withdrawn by three artificial orifices or canals from the same basin above the rapids; in this way the section of the outflow is enlarged, so that its own level is lowered, and there is an increase in the slope of the river above the falls, which in turn causes a lowering of the lake level. Owing to the configuration of the river most of the supply for the New York companies is derived from the main channel of Niagara River, leading to the greater falls.

THE POWER AVAILABLE.

"The mean discharge of the river from 1891 to 1905 was 204,000 cubic feet per second (of which only




Map of Niagara Falls.

10,000 cubic feet flowed down the channel on the American side of Goat Island). This amount corresponds to 4,900,000 horse-power. But at extremely low water the discharge falls to 158,000 cubic feet, or 3,800,000 horse-power. Both high and lower water are included in the mean volume. It is the low water which concerns the engineers. But on account of the position of the intakes, wheel-pits, waste-weir tunnels, etc., a third of the gross power is lost by the present engineering works. At this rate of loss the effective energy is diminished to about 2,500,000 horse-power. The Great Lakes act as huge reservoirs, so that the fluctuation of Lake Erie is remarkably small; the mean annual variation rarely exceeds a foot, though during shorter periods it may reach double this amount, and while storms are in progress it may increase to 4 feet or 5 feet. A change of level of 1 foot corresponds to over 500,000 gross horse-power at the falls.

"The Chicago canal is allowed to take 10,000 cubic feet per second, which is equal to 240,000 gross horse-power at Niagara, and more is asked for it. Under the treaty 20,000 cubic feet per second may be taken for power purposes in the State of New York; Canada is limited to 36,000 cubic feet per second, or over 800,000 gross horse-power, and of this some 500,000 net horse-power have already been conceded. Even this limitation of the diversion of the water amounts to 31 per cent of the low-water flow.

"Up to the present time less than 12,000 cubic feet per second (or less than 200,000 net horse-power) have been used on the New York side, and until lately only about 4,000 cubic feet per second were taken by the Chicago canal. On the Canadian side less than 6,000 feet per second were used in 1909. Accordingly not over one-third of the allowance under the treaty is taken at present, but the quantity is constantly increasing. Already the diversion is showing its effects on the falls, and this in the face of the prevailing high water, which has more than offset the lowering of Lake Erie on account of the diversion of the water.

THE LEVEL OF THE LAKES.

"There is a complete record of the level of Lake Erie since 1849, and fragmentary records since 1819. From this earliest date until 1836 it would seem that low water prevailed. Since the last-mentioned year, soon after which the water rose, we are now in the fourth cycle of high water, separated by periods of low water. The periods of high water have lasted from eight to twelve years, their inequalities being, perhaps, partially due to certain conditions of winter ice. But the periods exist; and as the high water has prevailed since 1902 we may be on the eve of another period of low water, of which there are indications. When the low water recurs the effect of the partial diversion will be fully seen on the falls themselves, which already show considerable changes, and upon the level of Lake Erie."

### Another Setback to Official Seismology

REVIEWING in the SCIENTIFIC AMERICAN the progress of seismology in America, we recently had occasion to deprecate the persistent refusal of Congress to make provision for the study of earthquakes under government auspices. We referred to the fact that the Weather Bureau was generally admitted to be more favorably situated than any other existing scientific bureau of the government for undertaking seismological work on a nation-wide scale, and that the chief of that bureau had repeatedly sought specific authority to this end.

It now transpires that at the last regular session of Congress the Weather Bureau did obtain a very slight concession from that body in the shape of an addition to its regular appropriation of the sum of $5,000, with the informal understanding between the chief of the bureau and the House Committee on Agriculture that this amount should be expended for seismological apparatus.

This opinion is controverted by a recent decision of the acting comptroller of the Treasury. This decision is based upon the connotations that, in the comptroller's opinion, can be assigned to certain words appearing in the organic and other laws relating to the bureau. Thus, the bureau is authorized to maintain "meteorological observation stations" and to "gage the climate of the United States." The comptroller rules, in effect, that seismology is not a proper function of a "meteorological observation station" and that earthquakes are not a part of "climate."

Opinions will differ as to the wisdom of this decision. Looking abroad, we find that a majority of the important meteorological stations of the old world maintain seismographs. Likewise, they carry on magnetic observations. Neither seismology nor terrestrial magnetism belong to meteorology, using the latter term in the restricted sense now current; but they require for their efficient posecution a similar organization. As to "climate," this word has so many meanings, according to the individual point of view, that it is idle to attempt to define its boundaries with a chalk-line.

This whole situation simply shows the haphazard and careless way in which Congress attempts to legislate on subjects of scientific importance. Whether or not the Comptroller is right in his construction of the law, the responsibility rests upon Congress to provide for the regular observation of earthquakes and for the study of the many practical problems of seismology. Surely the terrible devastation of San Francisco can hardly have been lost upon our legislators. As the matter now stands, nearly every civilized country maintains official seismological service, which usually forms parts of the official weather service. It seems almost unbelievable that the United States of America should be behindhand in such an important matter.

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